INVESTIGATION OF THE PERFORMANCE OF THE
I. H. C. 4M - 21 TILL PLANTER
FOR KANSAS AGRICULTURE

by

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INTRODUCTION

Description and Purpose for Design of the I. H. C. 4M-21 Till-Planter

In 1947 the International Harvester Company designed and built an experimental mulch planter. It was designed to prepare a seedbed, fertilize, and plant in a single operation in an undisturbed soil. It was designed to plant satisfactorily any row crop that can be planted with a conventional planter, providing the crop is fast growing and the weeds can be controlled with chemicals or mulch cultivating equipment.

The till-planter consists of two front-mounted tillage units with fertilizer attachments and a two-row rear-mounted planter with fertilizer units.

One of the tillage units is shown in Fig. 1; it was designed to perform in the following manner:

1. The upper 36-inch sweep operates at two to two and one half inches deep; its main purpose is to cut off weed roots while leaving trash on the surface.

2. The rolling coulters cut the trash ahead of the sweeps to aid in giving trash clearance for the beams.

3. The lower 18-inch sweep with inclined knives loosens a rootbed to a depth of seven to eight inches.

4. Fertilizer is deposited at the depth of the lower sweep from a fertilizer boot that is directly behind the lower sweep.

5. The four rotary-hoe wheels that are mounted behind the sweeps function to produce an eight-inch strip of seedbed and to drive the fertilizer attachment.

6. A special packer-wheel attachment can be mounted behind the

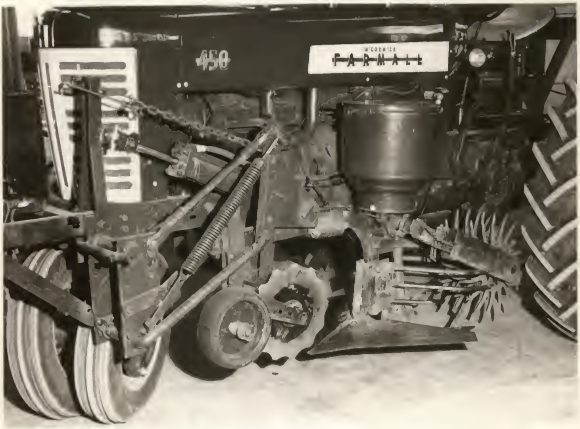


Fig. 1. The tillage unit of the I. H. C. 4M - 21 till-planter.

rotary-hoe unit. Its purpose is to aid in breaking up clods and preparing a firmer seedbed.

7. The trash rods that are mounted on the sweep beams and extend back and away from the beam on both sides push residue out away from the seedbed band while allowing loose dirt to filter through onto the seedbed band.

The rear-mounted planter was a conventional stub-runner planter. The fertilizer units on the planter were equipped with split-row boots that place the fertilizer shallow and close on both sides of the seed row.

From the preceding information it can be observed that the till-planter was designed to reduce labor and tractor requirements and to reduce erosion by leaving residues on the surface.

Purpose of Investigation

The till-planter is not considered to be an experimental machine by the manufacturer, but it has not come into extensive use in any locality.

The manufacturer, experiment stations, several midwestern colleges, seed companies, and a few selected farmers have tested the IHC 4M-21 till-planter, according to literature from the manufacturer.

However, detailed reports in regards to the above tests have not been widely published. Reports have been brief and little or no mention has been made as to crop response from till-planted crops as compared to other conventional methods.

Problems connected with the use of the till-planter have not been mentioned to much of an extent.

To the best of the writer's knowledge the till-planter had not been used in Kansas prior to this investigation.

The purpose of this investigation was therefore to find out as much as possible about the following things.

(1) Some of the problems connected with the use of the till-planter in row-crop production in Kansas with emphasis on corn production.

(2) Row crop response from till-planted row crops as compared to other tillage and planting methods in Kansas.

(3) Power requirements of the till-planter in several soils.

REVIEW OF LITERATURE

The Minimum Tillage Concept

Since 1950 several new methods of preparing seedbeds for corn have been tried. These new methods are aimed at a "minimum tillage" concept.

"Minimum tillage" as the new method has five aims according to Aldrich (1). These are as follows.

(1) To save labor by reducing the trips over the field.

(2) To reduce compaction.

(3) To increase water infiltration rate by leaving the surface loose and open.

(4) To reduce wind and water erosion.

(5) To reduce weeds by leaving the soil surface too loose for annuals to germinate and by causing the broken rootsticks of perennials to lose contact with the soil and dry out.

Page, et. al. of Ohio (18) suggested that a minimum amount of mechanical working of the soil would be appropriate. The tillage operation should loosen the soil, so that the natural aggregates are separated without being destroyed. Tillage beyond this point may be harmful. They also suggest that too much emphasis is being placed on seedbed preparation rather than rootbed preparation. Since seedbed requirements are not critical for the large seeded crops, it

would seem appropriate to concentrate on rootbed preparation.

Soil compaction is nationwide and its seriousness varies, according to research conducted by Nichols (15) at the National Tillage Machinery Laboratory at Auburn, Alabama. Farmers are using more and more heavy equipment which is causing a greater compaction problem. Soil compaction reduces water and air infiltration which in turn affects crop yield. Practice of the minimum tillage concept would decrease the compaction problem due to the reduced number of operations necessary to produce a crop.

Mulch Farming of Row Crops

Mulch farming came about as a result of the dust storms of the early thirties. Mulch farming is now practiced quite extensively in the semi-arid regions where wheat is the principal crop.

Lowdermilk (14) states:

> ....leaving crop litter, which is sometimes called stubble mulch or crop residue at the ground surface in farming operations is one of the most significant contributions to American agriculture. Certain adaptations of the method need to be made to meet the problems of different farming regions, but the new principle is the contribution of importance.

Since the late forties mulch farming has been the subject of research at several experiment stations where row crops are the principal crop grown.

The reason for the interest is that of obtaining the soil conserving benefits of mulch tillage. These are as follows.

(1) The mulch breaks the fall of the raindrop and thus absorbs part of the energy. This results in a decreased dispersing action on the soil structure.

(2) The mulch impedes the flow of water over the surface resulting in less sheet erosion.

(3) Mulch promotes infiltration through the maintenance of an open soil structure. Duley (8) found that a mulch-protected surface will maintain a high rate of intake for a considerable length of time.

From soil splash measurements taken in two years at Coshocton, Ohio, Harrold (11) reported an average of 12.7 tons of soil splash per acre on plowed plots and 7.5 tons per acre on mulched plots. Soil splash has been considered to be a measure of the effects of rain drop energy on erosion.

Measurements at this same station for the period of May to September of 1944 gave 2.74 inches of runoff and 25 tons per acre soil loss on plowed watersheds as against 0.82 inches of runoff and 0.27 tons of soil loss per acre on mulched watersheds.

Harrold (11) also stated in the above report that mulch culture for contour corn had the best record for erosion control with over a 90 per cent reduction in soil loss. The largest soil loss for any storm was 0.25 ton per acre; the corresponding value for corn on plowed land was 6.5 tons per acre.

Effects of Tillage Methods on Corn Yields

Mulch farming has not gained wide acceptance in the more humid areas. An important reason for this is that the crop yield is frequently lower under mulch tillage than with conventional plowing.

Browning and Norton (4) have carried on extensive investigations on tillage practices as they affect corn production in Iowa. They found that plowing gave the highest yields of any of the methods of tillage. Their experiences also showed that the plow was the most satisfactory for seedbed preparation for corn on slowly-drained soils. Nitrogen and potash deficiencies were evident when the seedbed was prepared by subsurface-tillage methods.

The cause for the nutrient deficiencies is thought to be caused by

micro-biological activity. Tillage studies were made in Iowa in 1952 and 1953 by Schaller and Evans (23) for the purpose of determining the effects of crop residue placement on micro-biological activity and nutrient availability.

The 1952 tests on a Webster silty-clay loam soil showed that corn yields were higher where corn stalks were removed or plowed under. Yields were reduced by 21 per cent on unfertilized plots and 28 per cent on fertilized plots where the crop residues were left on the surface. Nitrogen deficiencies were more pronounced on mulch-tilled plots at silking time. Weeds were more of a problem on the mulch-tilled plots. Mulch-tilling as mentioned here refers to conventional planting in a seedbed prepared by subsurface tillage. The seedbed was prepared in two operations using 24-inch sweeps, first at a depth of three inches and later at seven inches.

In 1953 similar tests on a Nicollet silt-loam soil at Ankeny, Iowa, were conducted. This soil was lighter in texture than the Webster soil of the 1952 tests. All corn yields were high and there was no significant difference resulting from different tillage methods. No significant differences in nitrogen, phosphorus, and potash content were found in an analysis of young plants and of leaves collected at silking time as a result of tillage.

Increased yields have been reported in drier regions from mulch-tilled corn where subsurface tillage was used in preparation of the seedbed. Duley and Russell (8), (9), found that mulch tilled corn yielded better than corn planted in a seedbed that had been plowed.

Hines, et al. (12) have done considerable research on mulch-tillage in Virginia. However the double-cut plow was used, and this resulted in about 50 per cent of the residue being covered. In a report of three years of experimentation they reported the following main difficulties:

(1) The effect of a surface mulch on nutrient availability.

(2) Regrowth of perennial grass and legumes following the initial tillage.

(3) Increased weed growth.

(4) Stand reduction.

They stated as a result of their experience that there was a need for a new mulch-tillage machine. One that would separate the dense vegetation from the soil, till and compact a four to eight-inch seedbed, and mix in an optimum amount of residue with the soil.

Browning (3) made a similar statement when he said

> A machine is needed that will prepare a seedbed so that the nutrient deficiencies will be minimized, crop production maintained, and still provide the protective action of the residues on the soil surface. If we had this machine, then we would still have to sell the farmer on changing from his present machine to this new type of machine. Until we have the machine and can show that crop yields are not reduced, farmers generally will not accept the practice of leaving crop residues on the surface.

Reports on the Till-Planter

Dr. Scarseth, Director of the American Farm Research Association, has tested the till-planter for seven years on a farm near Lafayette, Indiana, commencing in 1950. Scarseth (21) (22) stated that the soil on the farm was a heavy silty-clay loam, low in organic matter with a very compact clay subsoil. The average harvested yield for the seven year period was about 90 bushels per acre. The fertilizer bill ranged from 46 dollars per acre at first to 33 dollars per acre in 1957. No comparison with other methods of tillage and planting was reported.

In experiments conducted in New York, Aldrich (1) compared the till-planter method of corn planting with several other minimum-tillage methods. He found that yields were reduced where a strip of sod was left between the

rows, the greatest reduction being in dry years. Extra fertilizer had to be applied to make up for the nutrients not released from the unplowed strips.

Several disadvantages were noted, these being:

(1) Only two-row operation.

(2) The entire operation delayed until planting.

(3) Plant growth competes with sod strip.

(4) Extra fertilizer needed following sod.

(5) It is a special machine and it takes considerable power.

Brim and Johnson (2) have performed tests at Raleigh, North Carolina, on a double-cropping system involving soybeans and wheat. The till-planter was used to plant the soybeans in the wheat stubble as soon as possible after the wheat harvest. Some difficulty was experienced where straw accumulation was heavy. However, where a straw shredder was used or where the straw windrows were baled, stoppage was held to a minimum.

In 1953 and 1954 a comparison was made between till-planting and conventional planting on soybeans. In 1954 there was no appreciable rainfall after planting for two weeks. The till-planted soybeans came up good while the conventional-planted required irrigation to obtain a stand; however, the average yields were the same.

They stated that the till-planter required more power than was available on the average North Carolina farm, and that its use would also require an additional investment.

Power Requirement Measurements of Tillage Implements

Two schools of thought exist on the subject of power requirement measurements of tillage implements. One is that of performing the measurements in controlled soil conditions, and the other is that of performing the measurements

under natural field conditions.

Randolph and Reed (19) stated that the soil in any study must be treated as a dynamic material if the tests are to be used for correlation studies. They said that this was true, because the resistance of soil to the action of a tillage tool is constantly changing as a result of the effects of heat, light, water, bacterial and chemical action, and plant life. The resistance that a soil offers to a tool is also dependent upon the depth and character of the previous tillage. Therefore the tillage record of the test area must be taken into account.

Teleschi, et al. (25) stated that the main variables affecting draft are resistance to compaction, shear, friction, compression, cohesion, adhesion and speed. These variables were functions of composition and percentage of colloidal content, moisture percentage, bulk density, and the speed of the implement.

From tests conducted under controlled soil condition, they made the following report:

(1) As the moisture and clay percentages increase, draft increases with speed quite rapidly; at low moisture percentage speed does not affect the draft appreciably.

(2) Clay percentage does not affect draft at low moisture percentages; its effect increases with an increase in moisture percentage.

(3) The effect of moisture percentage was noticeable only when the clay percentage was quite high. Draft increased to the lower plastic limit and then decreased as the upper plastic limit was attained.

The overall results indicated that clay content was the main contributing factor affecting draft, and that sand and silt contribute only weight and some surface friction.

Nichols and Reaves (16) stated that to obtain reliable, consistent, and understandable results with different implements and soils, it is necessary to supplement and precede all tillage studies or tests of implements with physical measurements and studies of the soil material.

Randolph and Reed (19) found that the correction of draft data with reference to bulk density, moisture content, and clay content does not completely eliminate variations.

Clyde (6) stated that in tillage tests conducted by the Pennsylvania Agricultural Experiment Station, soil conditions have not been controlled. The tests were made under conditions varying from easy to difficult in order that a range of forces which a tool is going to encounter under normal conditions might be known. Clyde did not consider a five per cent error to be of much consequence in measuring and locating a force when soil conditions are not controlled and when judgment would be required in applying the data to implement design. Soil conditions were taken, however, to correlate results with those of the USDA Tillage Machinery Laboratory.

If a tool is supported by a frame that is entirely supported by force measuring devices, the soil reaction as well as any rotational forces can be determined. The Pennsylvania Agricultural Experiment Station and the USDA Tillage Machinery Laboratory at Auburn, Alabama, have used such devices for several years. In both devices the tool being tested is attached to a triangular subframe which is attached to the main frame by six hydraulic dynamometers. Each dynamometer is connected to a pen on a strip-chart recorder which also records time and distance. Three cells support the subframe, two push it forward, and one holds it sideways.

The Pennsylvania test unit is known as the tillagemeter and can be moved from one field to another according to Clyde (7). Lateral control is obtained

by metal wheels which run on movable steel-channel tracks. The depth is controlled by two rubber-tired wheels that run on undisturbed soil.

The USDA Tillage Machinery Laboratory testing unit operated on rails which were located on the walls between soil bins. Nine soil bins each 20 feet wide, 250 feet long, and six feet deep provided places for testing in 11 selected soils. Equipment was available for preparing the soil, sprinkling it, and protecting it from the weather. This allowed testing under carefully controlled conditions. Such an arrangement was particularly suitable for repetitive tests involving the comparison of different designs or tool adjustments, according to Reed (20).

Utilization of Strain Gages in Power Requirement Measurements

Principles of the Strain Gage. The electrical resistance of certain wires increases with tension. This increase is due to a change in length and diameter of the wire. The change in diameter occurs due to the effect of Poisson's ratio.

Hooke's law states that a constant ratio exists between stress and strain in various metals. The constant of proportionality that exists between stress and strain is known as the modulus of elasticity. From knowing the strain on a member, the stress can be calculated from the above relationship.

The wire used in bonded-wire strain gage construction has the property of linear variation of electrical resistance with strain. This linear relationship and the linear relationship of stress and strain are the principles which make possible the measurement of stress in metals with strain gages.

The Bonded Wire Strain Gage. The bonded wire strain gage is very small and light. It consists of a pattern of very fine wire cemented between two pieces of thin paper. The paper serves as a carrier of the grid and also

insulates the grid from the metal surface to which it is bonded.

After the gage has been bonded to a machine component for which a strain measurement is desired, it is connected to an electrical instrument which will indicate small changes in resistance. The change in resistance will give the change in strain on the test surface in the direction of the grid axis due to the previously mentioned linear relationships.

The SR-4 Strain Gage. The SR-4 strain gage in its present form was made possible by a rigid control of manufacturing processes. It was found that these gages could be made with a uniformity of resistance and gage factor such that individual calibration was not necessary.

The relationship between the change in gage resistance with a change in gage length is a dimensionless relationship called gage factor. It is expressed mathematically by the following formula: $F = \frac{\Delta R/R}{\Delta L/L}$

The greater the gage factor, the more sensitive the gage is to strain, and thus the electrical output to the recording instrument is correspondingly larger.

SR-4 gages are classified mainly by the filament material and by mounting materials.

The two predominant filament materials are advance wire and iso-elastic wire. Both have a good linear relationship between unit change in resistance and unit change in strain. However, the iso-elastic wire is from 50 to 100 times more sensitive to temperature than advance wire (24). The iso-elastic wire has about twice the gage factor of advance wire.

Two general types of mounting materials are used as filament carriers. These are paper impregnated with nitro-cellulose cement and paper impregnated with Bakelite cement. The grids are arranged in a variety of ways to meet specific requirements.

The Bakelite gages have been found to be more stable and can be operated at higher temperatures; (24) however, they are more expensive and harder to mount.

Basic Instrumentation. The Wheatstone bridge circuit is widely used for the precise measurement of resistance (17). The bridge is composed of four resistors connected in a definite pattern, a current source, and a sensitive galvanometer. The basic circuit is shown in Fig. 2.

For a balanced bridge shown in Fig. 2 it can be shown that the following relationship is always true. $R_1 R_3 = R_2 R_4$

This relationship is a most convenient method for determining the arrangement by which strain gages should be connected to give the desired results. For instance, if R_1 and R_2 are both increased by the same amount, the bridge will stay in balance. However, if R_1 and R_3 are increased by the same amount, the bridge will become unbalanced. If R_1 is increased and R_3 is decreased by the same amount, the bridge will stay in balance.

Thus it is easy to observe that if there are two active gages in a Wheatstone bridge both in equal strain of the same sense, they must be placed opposite in the bridge to measure total strain. However, if the strains of the two gages are equal in magnitude but of opposite sense, the bridge will remain in balance. This is a convenient method of cancelling out the strains due to bending stresses.

The above principles also provide a convenient method for deciding where dummy temperature compensating gages should be placed in the bridge. The gage that is compensating for the changes in another gage due to temperature must always be adjacent to it in the bridge. It must also naturally be located as close as possible physically to the measuring gage, so that they will be at the same temperature.

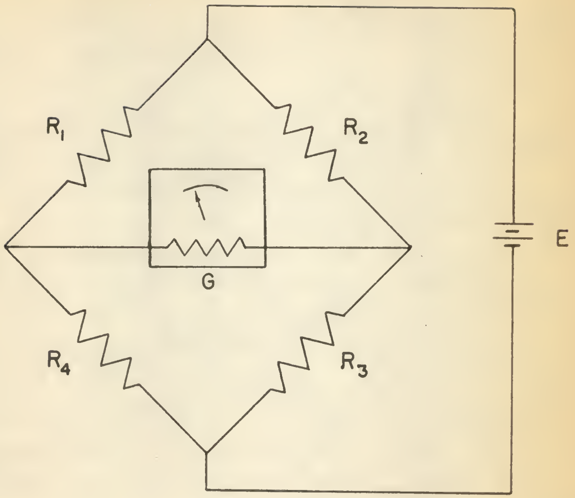


Fig. 2. The basic Wheatstone bridge circuit.

Power Requirement Measurements. The measurement of power through a rotating shaft is a measurement that is often needed. The use of strain gages makes this possible without losing any of the transmitted power and without disturbing the power train.

When a shaft is subjected to pure torsion, theoretical analysis has shown that principal strains occur on 45 and 135 degree helixes on the shaft. A strain gage placed along one of these helixes will be subjected to either tension or compression.

Since the principal strain is proportional to the applied torque up to the elastic limit, the measured strain is in effect a measurement of the torque.

Most shafts transmitting torque are also subjected to bending at the same time. The strain on the measuring gage caused by bending stress must be cancelled out if the gage is to measure only strain caused by torsional stress.

This is accomplished by using four active gages on the shaft to form a Wheatstone bridge. Two of the gages are placed diametrically opposite on a 45-degree helix, while the other two are placed on a 135-degree helix in the same manner. The two gages located on the same helix are connected as opposite legs in the bridge. This placement causes the gages in opposite legs of the bridge to sense the same magnitude of strain due to bending, but it is of opposite sense. Therefore the bridge is not unbalanced from the effects of bending.

Temperature compensation is not a problem, because all four gages are active and are closely located on the same member.

A collector of some sort must be used to form a continuous circuit from the rotating bridge to the recording instruments. The slip ring and brush collector is satisfactory for some installations. However, according to

Burrough (5), the lower limit for accurate results is around 6000 psi in torsion.

Burrough designed and used a mercury bath collector for use in measuring the power and torque distribution in farm machinery drive shafts. This collector gave the desired characteristics of stable contact resistance and equal resistance under static and dynamic loads. Laboratory tests showed that the resistance of the collector varied from .00585 ohms under static conditions to .00565 ohms at 2500 rpm. The lower limit for this collector was approximately 350 psi in torsion.

Jenson (13) set forth a method by which information sufficient to obtain engine horsepower developed and the power requirements of implements simultaneously could be obtained.

A strain gage dynamometer was used to obtain the implement draft requirements. The dynamometer was simply a steel ring fastened to the front end of the drawbar. Four gages were placed on the ring, so that two would be in tension and two in compression when pull was applied to the drawbar. The two gages in tension were placed opposite in the Wheatstone bridge circuit with compression gages placed in the same manner to complete the bridge. This arrangement gave self-compensation for temperature and for bending in the horizontal and vertical planes.

The dynamometer was calibrated in a tensile-testing machine for drawbar pull versus meter deflection.

Strain gages were placed on a reduced section of the transmission drive shaft for the purpose of obtaining the engine horsepower output. A slip ring collector completed the electrical circuit to the rotating bridge.

The meters from the drawbar dynamometer and the drive shaft bridge circuits were mounted together with an engine tachometer, drive-wheel and front-wheel

revolution counters, and a stop watch. Simultaneous recording of all the information was accomplished by photographing the panel with a 35 mm automatic camera.

Jenson also mentioned a method for measuring the draft of integral tools mounted with three-point linkage. A transducer element was used at each hitch point. Each transducer was mounted to a hitching point, so that the beam of the transducer was vertical. By placing a complete four-gage bridge on each beam, the bending moment caused by the component of draft in the direction of the line of travel was measured. This bending moment was proportional to the component of force perpendicular to the axis of the beam regardless of direction of travel. The three bridges were wired in parallel, so that the meter output was the algebraic sum of the output from the three bridges, or net implement draft.

CROP PLANTING EXPERIMENTS

Till-Planter, Plow-Planter, and Surface-Planter Methods of Planting Compared on Corn Planted in Alfalfa Sod

This experiment was conducted on the Kansas State Agronomy Farm during 1958.

Four plot plantings were made; each plot was four rows wide and 130 feet long. The rows were spaced 40 inches apart for all methods of planting. The four planting methods were as follows:

1. Till-planter with a pre-emergence spray.
2. Till-planter without spray.
3. Plow-planter.
4. Surface-planter.

The plot locations for the above plantings were randomized. The soil was classified as a silty-clay soil.

All of the planting was accomplished on the same day in the second week of May. Nothing had been done to the till-planter and plow-planter plots prior to the day of planting. Therefore, a 12-inch top growth of alfalfa covered the ground. The surface-plant plot had been spring plowed; two diskings and one harrowing operation followed before planting.

The plow-plant plot was plowed in the conventional manner; this operation was followed immediately with that of planting.

The planting rate was about 10,000 kernels per acre for all methods of planting. The corn stand was later thinned to 7,500 plants per acre. No fertilizer was applied.

The pre-emergence spraying was accomplished on one of the till-planter plots simultaneously with planting. The sprayer boom for the sprayer extended out behind the planter wheels so that the soil was undisturbed after it had been sprayed. The entire row was sprayed with Simazin at the rate of four pounds per acre.

Several difficulties were encountered while planting the till-planter plots. The tillage units would not penetrate the soil sufficiently to keep the entire cutting edge of the upper sweep beneath the surface. The rear two-inch portion of the sweep did not cut off the alfalfa, as a result clogging occurred between the upper sweeps under the tractor.

Several adjustments were made to correct the situation. The pitch was increased on the sweep units to give better penetration. However, this did not decrease the problem of clogging. Increasing the pitch on the sweep units increased the operating depth for the sweep point and decreased the operating depth of the sweep blades at the rear for a given position. Therefore a deeper

operating depth was necessary to keep the entire sweep cutting edge beneath the surface. This could not be done because it required more power than was available.

The surface-planter corn emerged from the ground first; it was followed by the plow-plant corn. This same trend was observed in the rate of growth of the corn for the plots for the early part of the summer.

Little difference could be noted between the plots a few weeks after the corn had tasseled and from that time forward.

All of the plots required cultivation for weed control; the effect of the pre-emergence spray could not be noted.

Yield differences between planting methods varied from two to three bushels per acre with the average yield being 80 bushels per acre. The yield differences were considered insignificant.

Till-Planter, Lister, and Surface-Planter Methods of Planting Corn Compared at the Belleville Experiment Station

This experiment was conducted in 1958 on the Belleville Experimental Station which is located in North Central Kansas. The soil on the plot area was a silty clay soil. This soil was lighter in texture than the soil of the previous experiment. The previous crop grown was grain sorghum; the crop residue remaining was light.

The plots were four rows wide and 265 feet long; the rows were spaced 40 inches apart. Twenty plots were laid out so that five replications could be made for each test. The plots within each replication were designated randomly.

The following plots made up each replication:

1. Till-planter with pre-emergence spray.
2. Till-planter without spray.

3. Lister.

4. Surface-planter.

The plots were split at the center along the plot length, so that two fertilizer rates could be compared for each of the planting methods. This is termed a split-plot experiment, the main plot then consisted of two sub-plots. The sub-plots were randomized within the main plot for each plot.

The plots designated for surface planting were spring plowed, the plowing was followed by several conventional tillage operations later on in the spring. The plots designated for listing were disked early in the spring; the till-planter plots received no tillage.

All the plots were planted on the same day during the third week of May. The surface-planter plots were planted with the rear-mounted planter unit of the till-planter. The tillage units were lowered just enough to operate the rotary-hoe units, so that the fertilizer units would operate. The lister plots were planted with a conventional lister.

The planter units were set to deliver 10,000 kernels per acre; this was checked by observing the distance between kernels.

Nitrogen in the form of 33 per cent ammonium nitrate was distributed on all the plots. The rate of nitrogen distributed in terms of pounds of nitrogen per acre for each plot was controlled; so that one of the sub-plots received a rate of 50 pounds of nitrogen per acre and the other 100 pounds of nitrogen per acre.

All the fertilizer units on the till-planter were utilized in distributing the nitrogen on the till-planter and surface-planter plots. Since the front fertilizer units were driven off of the rotary-hoe units, a laboratory calibration of the units was not possible. Therefore all calibration was done in the field; the final settings distributed nitrogen at a rate of 57 pounds per

acre in the front units, and 42 pounds per acre in the rear units. Both units were operated on the sub-plot receiving the heavy fertilizer treatment, the rear units were disengaged while planting the sub-plot receiving the light treatment.

The pre-emergence spraying was accomplished simultaneously with planting on the till-planter plots designated for spraying. Simazin was applied at a rate of four pounds per acre in the same manner as mentioned in the preceding section.

Since the crop residue was not heavy, little trouble was encountered with residue clogging between the sweep units; however, a great deal of stoppage was caused by soil packing in between the rotary-hoe wheels. The culti-packer wheel units would stop the rotary-hoe wheel rotation after the soil built up enough. The culti-packer wheel units were the source of the difficulty. In plantings made later under similar conditions the culti-packer units were removed; no difficulty was encountered. Under drier conditions the culti-packer units would probably not cause this trouble, and they would perform in the proper manner.

During the early summer there was quite a difference in growth progress between methods of planting. The surface-planted plots were always ahead, the listed plots were always the most retarded. The till-planted plots were just about in between the two. By the end of July, however, the differences had disappeared.

One cultivation was necessary for all of the plots; it was accomplished about three weeks after planting. Some difficulty was encountered while cultivating the till-planter plots. Crop residue collected between the two front shanks causing stoppage. It was also necessary to add weight to the rear cultivator units so that they would penetrate the soil effectively. The main

source of this difficulty was probably the wheel tracks made at the time of planting.

Weed control was the poorest in the till-planter plots. Most of the weeds were located between the rows. The weeds that the upper sweeps missed during the planting operation were evidently missed during cultivation. Even if the upper sweep cut out their full width, a four-inch band was left in the middle. This band was hard to cultivate, especially in the wheel tracks. Therefore, it was difficult to kill the plant growth in this area.

The two center rows were harvested from each sub-plot for a distance of 46.67 feet. This arrangement provided a simple means for obtaining the yield in terms of bushels per acre since it was equal to the pounds harvested times two.

The following data were recorded for each sub-plot:

1. A stalk count.
2. Plants lodged in terms of root lodging and stalk lodging.
3. Pounds of dropped and lodged corn picked.
4. Pounds of corn picked.

The stalk and lodged stalk counts were made first, then the dropped and lodged corn ears were picked. Corn ears were classified as lodged if the stalks were broken below the ear.

Table 1 shows a summary of means of the data obtained from the five replications for each planting method.

A statistical analysis of the complete data was performed by the Experimental Station Statistical Laboratory.

An analysis of variance was run for dropped and lodged corn, total corn yield, and the stalks per acre. The sources of variation in each of the above analyses were as follows: method of plantings, replications, main plot error,

Table 1. Summary of the harvesting data from the corn plots at the Belleville Experiment Station.

Method of Planting	Dropped and lodged corn in Bu/Acre		Total corn yield Bu/Acre		Stalks per acre		Stalks lodged per acre	
	100# N	50# N	100# N	50# N	100# N	50# N	100#N	50#N
Till-planter sprayed	7.60	8.28	96.28	87.48	10,948	10,080	700	1076
Till-planter	4.64	9.88	90.40	81.56	9,464	10,836	532	1004
Lister	7.28	5.56	99.76	86.68	10,444	10,108	744	644
Surface-planter	20.64	13.40	91.96	84.92	13,216	11,760	3248	2912

fertilizer rate, method x rate, and sub-plot error.

The F test was employed to determine whether or not the variance was significant for each source; cut-off was set at the five per cent level. F is a value expressed by the following relationship: $F = \frac{\text{Variance of Source}}{\text{Overall Experiment Variance}}$

The determination in regards to significance is obtained from an F distribution table.

In the analysis of the dropped and lodged corn the method of planting and the replications had significant F values. These were at the one-half per cent and the one per cent levels respectively. More will be said later about the differences in dropped and lodged corn due to the method of planting. The reason for the differences in dropped and lodged corn within replications was not known. A hard rainstorm with high winds from a northeastwardly direction had caused the corn to be bent over more on the replications located on the east side. The replications with the highest dropped and lodged corn rates were located about in the center of the test block.

For total corn yield only the fertilizer rate was significant, and it was significant at the five per cent level, which was the cut off level used.

Method of planting and method x rate were significant in the stalks per acre analysis. These were at the one per cent and two and one half per cent

levels respectively.

The F test has shown that differences due to sources of variation exist, but it has not shown how many differences there are. Least Significant Differences or LSD's were computed by the Experimental Station Statistical Laboratory to compare the individual overall means of dropped and lodged corn, total corn yield, and stalks per acre.

The only difference occurring in the overall means of the dropped and lodged corn was that of the surface-planted corn. The same was true for the stalks per acre overall mean. Therefore it appears that the difference in dropped and lodged corn might have been due to an increased plant population as well as to the method of planting.

Fertilizer treatment was the only thing that showed up as being significant in the overall mean values for yield. The increase in yield due to fertilizer treatment was the greatest for the listed corn; however, the F test failed to show any difference in the method x rate sources of variations as has been previously inferred. In other words there appeared to be no significant interaction between the planting method and the fertilizer treatment.

Till-Planter, Lister, and Surface-Planter Methods of Planting Corn Compared at the Courtland Irrigation Experiment Field

The Courtland Irrigation Experiment Field is located in the same vicinity as the Belleville Experimental Station. The soil was a silty clay soil also, but it appeared to be lighter in texture. The previous crop grown was grain sorghum; the amount of crop residue remaining was light.

The test block was laid out on an area possessing a gentle, uniform slope. The block was of sufficient width to accommodate 16 plots, each consisting of four 40-inch rows with some additional border rows. The plots were 200 feet long.

Four replications were made for each of the following planting methods.

1. Till-planter with pre-emergence spray.
2. Till-planter without spray.
3. Lister.
4. Surface-planter.

The plots designated for the above planting methods were randomized within replications.

The plots designated for surface planting were spring plowed, this was followed by disking and harrowing later, just prior to planting. The lister plots were spring disked prior to the date of planting; the till-planter plots were left undisturbed.

The plots were all planted during the third week of May; the till-planter plots were planted two days before the lister and surface-planter plots. The surface planting and the listing were done with conventional equipment.

The planters were all set to deliver as near to 18,000 kernels of corn per acre as was possible.

Nitrogen in the form of ammonium nitrate was distributed on all plots at a rate of 100 pounds of nitrogen per acre, or in other words, 300 pounds of 33 per cent ammonium nitrate per acre.

The pre-emergence sprayed plots were sprayed in the same manner and at the same rate as they were on the Belleville Experimental Station plots.

During the early part of the growing season, the till-planter plots seemed to be slightly ahead of the surface-plant plots. The lister plots appeared to be somewhat retarded. The two-day head start that the till-planter plots had might have caused the reversed trend from what was observed at the Belleville Experimental Station. By the end of July the differences had disappeared, just as they did in the other experiments.

All of the plots were cultivated once; furrowing for irrigation was performed early in July. Weed control was excellent in the surface-planter and lister plots. The sprayed till-planter plots had some weeds between the rows; the unsprayed till-planter plots had weeds in the row as well as between the rows. The majority of the weeds were located on the strips that the upper sweeps did not cover for all of the till-planter plots.

Three applications of water were made; a total of 12 inches of water was applied during July and August.

The two center rows were harvested from each plot for a distance of 65.3 feet, so that one hundredth of an acre was harvested from each plot. Harvesting was initiated at approximately 65 feet in from the end of the rows.

A stalk count and the picking of the down and lodged corn were accomplished first. Table 2 is a summary of the mean values obtained from the harvesting data.

Table 2. Summary of the harvesting data from the irrigated corn plots at the Courtland Irrigation Experiment Field.

Method of planting	Stalks per acre	Down and lodged corn in Bu/Acre	Total yield Bu/Acre
Till-planter with spray	20,825	6.84	128.9
Till-planter	19,333	4.43	139.7
Lister	18,400	6.68	142.4
Surface-planter	17,433	3.93	133.1

The data were analyzed statistically as they were in the previous experiment. An analysis of variance was performed for total yield and stalks per acre. The sources of variation for each of the analyses were as follows: planting methods, replications, and error.

The F test was employed again to determine whether or not differences were significant. The five per cent level was used as the cut-off point to determine significance.

The results of the analysis indicated that the yield differences were insignificant for planting methods and significant at the five per cent level for replications. The variation within replications shows the importance of having several replications.

The difference in stalks per acre was significant between methods at the five per cent level. However, it was insignificant between the replications.

Least Significant Differences were computed by the Experiment Station Statistical Laboratory to compare the overall means of the corn yields and stalks per acre. The LSD for the corn yield was 14.9 bushels per acre. Therefore, a difference of 14.9 bushels per acre had to exist between the overall mean yields to have significance. The fact was known that significance did not exist from the F test; however, the yield difference necessary for significance was not known from the test alone.

A difference of 13.5 bushels per acre did exist between the yield means of the sprayed till-planter corn and the lister-planted corn. This was the largest difference, as can be noted from Table 2. However, it is less than 14.9; so it is an insignificant difference. The difference between the unsprayed till-planter corn and the sprayed till-planter corn was 10.8 bushels per acre.

Till-Planter, Lister, and Surface-Planter Methods of Planting Compared on Milo at the Belleville Experimental Station

The testing block was laid out on a location that was nearly flat. The soil was of a silty clay type, the previous crop grown was corn. The surface residue remaining was light.

Sixteen plots were laid out on the test block; the plots were four 40-inch rows wide and 350 feet long. The four following methods of planting were compared.

1. Till-planter with spray.
2. Till-planter without spray.
3. Lister.
4. Surface-planter.

Therefore four replications were made for each method; randomization was used to designate the plots within each replication for the planting methods.

The till-planter plots received no tilling prior to the planting operation. The lister plots had been spring disked; the surface-planter plots had been spring plowed, disked, and harrowed.

All of the plots were planted on the same day. The planters were set to plant four pounds per acre. The surface-planter plots were planted with the rear-mounted planter of the till-planter. The tillage units were lowered just enough to allow the rotary hoe units to operate.

Fertilizer in the form of 33 per cent ammonium nitrate was distributed on all of the plots at a rate of 300 pounds of nitrate per acre or in other words, 100 pounds of nitrogen per acre. The fertilizer was distributed with a drill on the lister plots; both the front and rear fertilizer units of the till-planter were utilized for fertilizer placement on the surface-plant and till-planter plots. Fifty-seven pounds of the total rate were applied by the front units.

The till-planter with spray plots were sprayed with Simazin at a rate of four pounds per acre. This was accomplished simultaneously with the planting.

A poor stand was obtained for the till-planter and surface-planter plots while the lister plots had a good stand. The planting rate was evidently less

for the till-planter than it was for the lister. It is not logical to assume that the seed planted in the lister plots had the best seed bed. A considerable amount of rain fell before the milo emerged; it would seem that this would have affected the lister plots the most.

A chinch bug infestation in the plots caused a wide variation in rate of growth between the planting methods. The lister plots got a good start and did not appear to be affected by the chinch bugs; however, the other plots seemed to be retarded by the infestation.

The lister plots were ahead of the other plots throughout the summer; even with a thicker stand their growth was taller at the end of the growing season.

The sprayed till-planter plots grew slower and attained less height than the rest of the plots. It was apparent that the Simazin spraying retarded the growth. Its effect on the stand is not known because stand counts were not made. The sprayed plots, however, appeared to have as good a stand as the surface-planter and the unsprayed till-planter plots.

The weed control obtained from the pre-emergence spray was excellent. Hardly a weed existed on any of the Simazin-sprayed plots. The lister plots were relatively free from weeds. The surface-planter and till-planter plots were both heavily infested with weeds and grass. The surface-planter plots were the worst since more grass existed on them. All of the plots received the same number of cultivations.

Each complete plot was harvested with a combine. The stalks were leaning badly from a rain storm. Therefore many heads were missed by the combine.

The overall means of the yield rates for the four replications are shown in Table 3.

Table 3. Summary of the harvesting data from milo plots at the Belleville Experimental Station.

Method of Planting	Overall Mean Yield in Bu/Acre
Till-planter, sprayed	37.84
Till-planter	51.96
Lister	67.64
Surface-Planter	47.46

The harvesting data were statistically analyzed; an analysis of variance was performed for total yield. The sources of variation were planting methods, replications, and error.

The F test was utilized once more to determine whether the differences were significant.

The planting methods were significant at the one half per cent level. Replications were significant at the five per cent level.

The Least Significant Difference was found for the overall mean yields. It was found to be 6.368 bushels per acre. Applying this value to the mean yields in Table 3 shows that several significant differences occurred. The sprayed till-planter milo yield plus the LSD does not exceed or equal any of the other yields. The lister milo yield minus the LSD does not equal or go below any of the yields. Therefore the sprayed till-planter milo yield was significantly lower than the rest; while the lister milo yield was significantly higher than the rest. The till-planter unsprayed milo had a 4.5 bushel per acre better yield than the surface-planter milo; however, this was insignificant since it was less than 6.368.

The above analysis of the data certainly showed that the lister milo plots were by far the best. However, it would not be logical to say that this was all due to the method of planting. The chinch bug effect was no doubt the cause of quite a portion of the difference.

Utilization of the Till-Planter in Double Cropping Systems

More land is being brought under irrigation each year in Kansas. The double-cropping system lends itself well to irrigation farming in Kansas if the second crop has enough time to mature. Therefore it would be logical to assume that the practice of double cropping will be increased in the future.

The till-planter has quite a potential for use in the double-cropping system. A crop can be planted and fertilized in one operation; a pre-emergence spray can also be applied simultaneously with the planting if the additional equipment is mounted on the tractor and the rear-mounted planter unit. This operation can be accomplished right behind the combine without any seedbed preparation. Since time is quite a factor in the double-crop system, this provides a great advantage in certain cases.

Two experiments involving the use of the till-planter in the double-cropping system were conducted during the summer of 1958.

One of the experiments was a wheat-milo double-cropping system. The milo was planted as soon as possible after the wheat had been harvested. Several rains prevented getting the crop planted earlier.

The experiment was conducted on a farm located in the Kansas River Valley and the soil was of a loam type. Three acres of milo were planted with the till-planter alongside approximately 12 acres of listed milo.

The milo was planted during the second week of July at a rate of 10 pounds per acre for both methods of planting. The whole field had received an application of anhydrous ammonia prior to the planting at a rate of 100 pounds of nitrogen per acre. This operation would not have been necessary for the area designated for the till-planter method of planting, but it was the procedure practiced by the farm operator.

Fertilizer in the form of 25-45-0 was applied at a rate of 100 pounds per acre on the till-planter milo. Only the rear fertilizer units were utilized to distribute the fertilizer. The lister-planted milo received no additional fertilizer.

The crop residue was heavy, and the soil was wet when planting was accomplished. Planting with the till-planter was next to impossible under the existing conditions. The soil was relatively loose; therefore the sweep units were afforded little downward force from the pitch on the sweeps. Changes were made on the sweep units; these changes are outlined in the next section.

Little stoppage due to residue clogging occurred after the changes had been made. The tillage units were operated so that the upper sweep blade tips were just beneath the surface. This left most of the crop residue on top of the ridges, where it could give protection. When the straw started to clog between the sweeps, lowering the operating depth slightly usually corrected the condition.

The lister-planted milo was planted two days later than the till-planter milo. Plate I shows a comparison of the two plantings eight days after the till-planter milo had been planted. About six inches of rain had fallen during this time interval.

The increased protection afforded by the additional crop residue between the till-planter rows was quite apparent. Although the immediate area on either side of the till-planter rows are unprotected, the ridges were well protected by the straw mulch.

The lister ridges were steeper and had less residue on the surface between the rows. Erosion appeared to be less in the till-planter milo than it was in the lister milo.

EXPLANATION OF PLATE I

Fig. 1. Till-planted milo eight days after planting in wheat stubble.

Fig. 2. Listed milo six days after planting on same field as Fig. 1.

PLATE I

Fig. 1

Fig. 2

Two cultivations were performed on both milo plantings to control weed and wheat volunteer growth. Lister-cultivation equipment was utilized; this equipment provided good weed control for both plantings. This equipment mixed the surface residue in with the soil too much. After the two cultivations the till-planted milo had only a small amount of surface residue remaining; the lister milo had a slight amount less.

The till-planter milo appeared to be slightly ahead of the lister milo throughout the growing season. This was probably due more to the additional starter fertilizer and the earlier planting date than to the different planting method.

The milo was chopped up and blown into a silo since it did not mature properly. Failure to mature was caused by an early September frost. Yield data were not taken.

The second experiment with double-cropping was conducted on the Ashland Agronomy Farm. The soil was very similar to that of the previous experiment. Soybeans were planted in wheat stubble during the second week of July. The wheat had been harvested a few weeks earlier; rains prevented an earlier soybean planting.

The crop residue remaining was excessively heavy, and the soil was wet. The modified upper sweeps and the repositioned lower sweep were used on the tillage units; little stoppage due to clogging of straw was experienced.

Approximately two acres of soybeans were planted with the till-planter alongside an equal acreage of surface-planted soybeans. No fertilizer was distributed. The surface-planted acreage had been plowed, disked, and harrowed prior to planting.

The till-planter soybeans got off to a better start, but the difference

did not last long. The high amount of rain that fell during the summer was favorable for the surface-planter soybeans.

The till-planter acreage did not receive its first cultivation as soon as the surface-planter acreage. This was due to the fact that the surface-planter acreage dried out faster, and it was cultivated between two rains. With all of the straw on top of the surface the till-planter acreage did not dry off enough for cultivation between the rains.

The soybeans matured before the early frost; however, yield data were not taken.

TILLAGE UNIT DESIGN MODIFICATIONS

Tillage unit modifications came about as a result of some adverse planting conditions. A heavy wheat straw accumulation existed on the surface, and the soil beneath was loose and wet. The soil afforded little downward force from the existing pitch on the sweeps.

Changing the pitch of the sweep units did not correct the conditon; several settings were tried unsuccessfully. Increasing the pitch of the sweep units did give the points a steeper angle of attack, but it also raised the rear portions of the sweep blades. As the pitch was increased, a point was reached at which the entire cutting edge of the upper sweep could not be operated beneath the ground. When it could, power was not sufficient. The ridges obtained from the operation were more like lister ridges.

With the rear two-inch portions of the upper-sweep cutting edges operating above the surface, clogging occurred between the two upper sweeps and the upper and lower sweep points.

Two changes were made on the sweep units in an attempt to correct the condition. These were as follows:

1. The point of the upper sweeps were given additional pitch.

2. The lower sweeps were repositioned.

Plates II and III show profile views of an original and a modified upper sweep to show the effects of the modification.

The idea of increasing the pitch on the point was to get additional downward force from soil reaction without tipping the whole sweep forward. More was obtained from the change than just the pitch increase on the point. The change caused the sweep blades to be inclined at a steeper angle with the ground surface.

Plate IV shows a comparison of the original and modified upper sweeps mounted on the sweep units with the units at the approximate ground penetration angle.

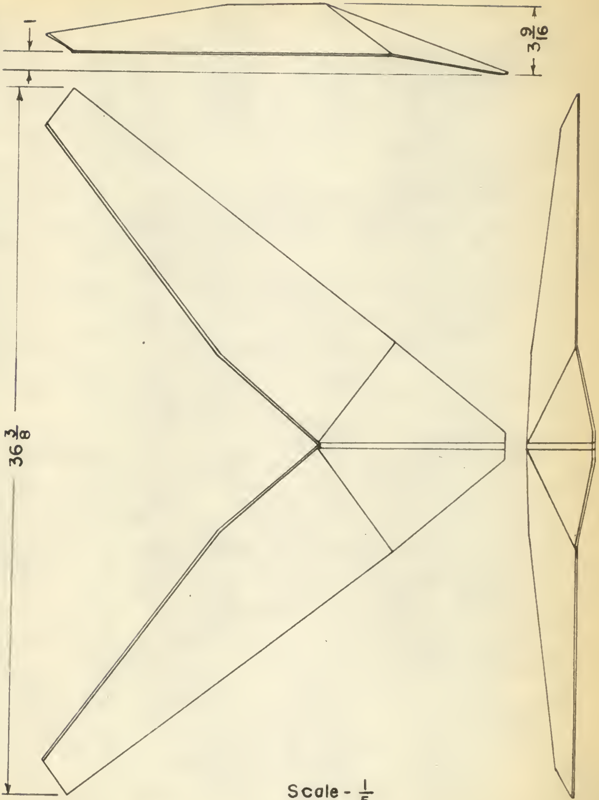
The overall effect of the sweep modification was to lower the entire cutting edge of the sweep with respect to the sweep frog. This allowed the upper sweep to contact the surface sooner after the lower sweep had made contact. Therefore less surface residue could collect between the two sweep points during the time interval between lower sweep and upper sweep ground contact. Once the point of the upper sweep made contact, the residue was cleared away ahead of the lower sweep. This effect and the increased suction greatly reduced the clogging of crop residue in the tillage units.

A comparison between a sweep unit equipped with a modified upper sweep and one equipped with a standard upper sweep is shown by Plate V also. The units are shown in operating position rather than in ground contact position. The comparison shows that for a given operating depth of the lower sweeps the modified upper sweep will be doing more work than the original sweep. It would appear, however, that this would reduce the load on the lower sweep.

EXPLANATION OF PLATE II

Profiles of an original upper sweep.

PLATE II

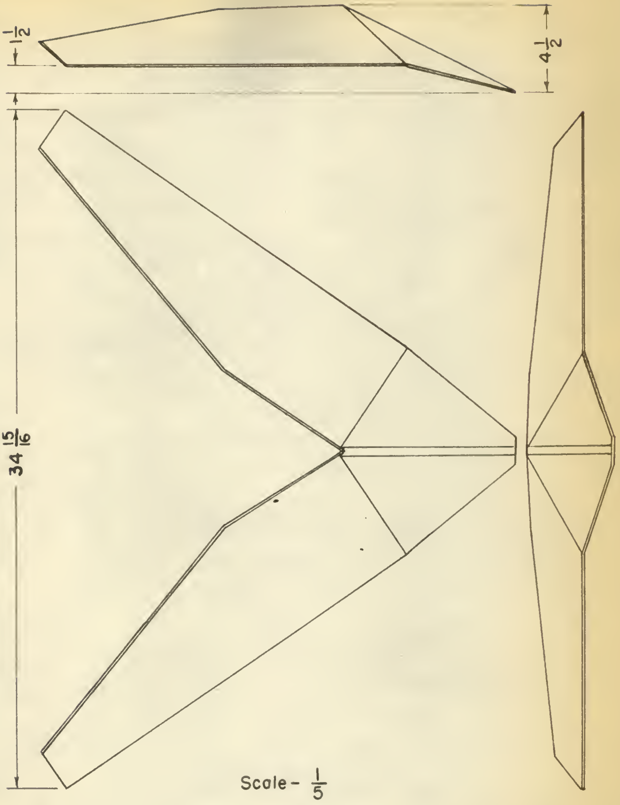


Scale - 1/5

EXPLANATION OF PLATE III

Profiles of a modified upper sweep.

PLATE III



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EXPLANATION OF PLATE V

Fig. 1. The original sweep unit at the approximate ground penetration angle.

Fig. 2. The sweep unit equipped with the modified upper sweep at the approximate ground penetration angle.

PLATE V

Fig. 1

Fig. 2

EXPLANATION OF PLATE VI

Fig. 1. The original sweep unit in standard operating position.

Fig. 2. The sweep unit in standard operating position equipped with the modified upper sweep.

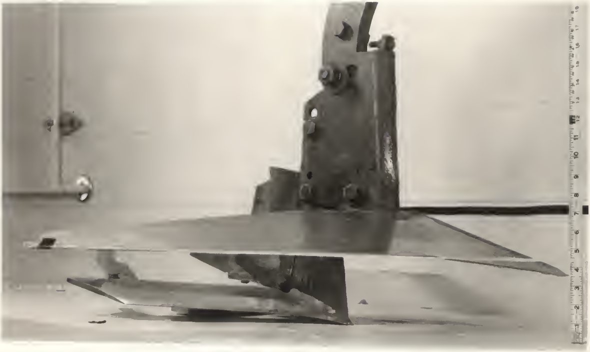


Fig. 1

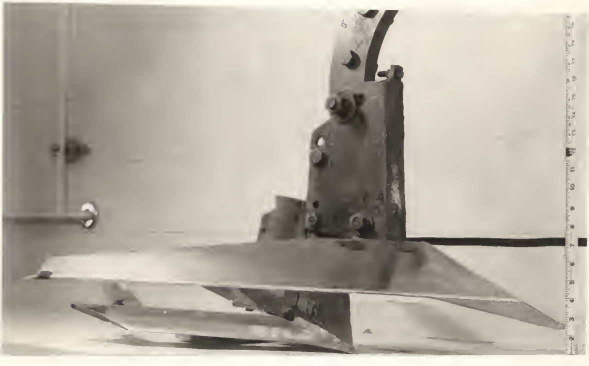


Fig. 2

Plate VI shows the repositioned lower sweeps; the lower sweeps were moved back a distance of three inches. No change was made with respect to the vertical position; the mounting was parallel and at the same level as the original mounting.

It was apparent that the upper sweep modification was largely responsible for the improved performance of the tillage units.

POWER REQUIREMENT MEASUREMENTS OF THE TILL-PLANTER

Reasons for Conducting Power Requirement Measurements

The review of literature and the actual use of the till-planter in crop experimentation indicated that the till-planter consumed a considerable amount of power. No mention was made as to the horsepower requirements of the till-planter in any of the literature written about the till-planter.

The reasons for making the power requirement measurements were as follows:

(1) To determine the total rear axle power required by the till-planter in several soils at several speeds.

(2) To determine what percentage of the axle power was consumed by the tillage units in several soils at several speeds.

(3) To determine the slip of the drive wheels and to determine the power lost due to slip in several soils and at several speeds.

(4) To determine whether the tillage-unit modifications previously mentioned caused any noticeable change in the power requirements of the till-planter in several soils and at several speeds.

EXPLANATION OF PLATE VI

Fig. 1. The sweep unit equipped with the original upper sweep and the repositioned lower sweep at the approximate ground penetration angle.

Fig. 2. The sweep unit equipped with the modified upper sweep and the repositioned lower sweep at the approximate ground penetration angle.

PLATE VI

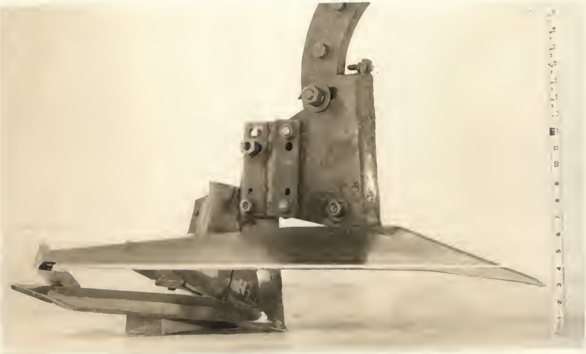


Fig. 1

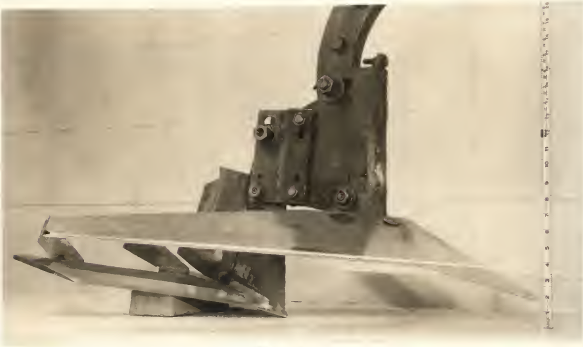


Fig. 2

Method for Measuring the Tractor Axle Horsepower Required by the Till-Planter

Since the torque input to a conventional differential is equally divided between the axles, a measurement of the power transmitted through one of them should be one half of the power transmitted to the rear wheels.

Two CX-1 Baldwin Lima strain gage rosettes were attached to the right rear axle of the tractor. The rosettes were placed midway between the axle housing and the wheel hub and diametrically opposite on the axles. Each rosette was orientated, so that each strain gage element would be aligned on a principal strain axis.

A template made of paper gasket material greatly simplified the orientation and gluing of the rosettes on the axle.

Alignment lines for orientation of the rosettes and lines showing the rosette outlines were laid out on a strip of material ten inches wide and of a length equal to the circumference of the axle. The material that was enclosed by the outline of the rosettes was removed, so that the rosettes could be glued onto the axle with the template in place.

The individual elements of the rosette were connected as shown by Fig. 3 to form a Wheatstone bridge. This makes possible the measurement of the principal strain while cancelling out the effects of bending stresses and changes in temperature as mentioned in the review of literature.

Since the Wheatstone bridge circuit was on a rotating member, a method of transferring the rotating circuit into a stationary circuit was needed.

A mercury bath collector designed similar to the one mentioned in the review of literature was constructed and used for this purpose. This collector had four individual cells to accommodate the four leads from the bridge.

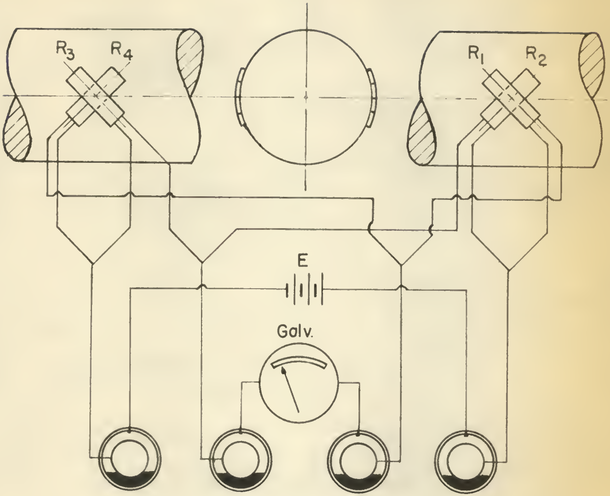


Fig. 3. Schematic wiring diagram of the bridge circuit utilized in measuring axle torque with R_1 , R_2 , R_3 , and R_4 located the same within the bridge as they were in Fig. 2.

Each lead terminated at a brass disk where it was soldered to the disk. The disks were glued to a plastic sheath which was slipped over the brass tube shaft. The disks rotate in a pool of mercury; the circuits are completed to the outside terminals by copper rings that encircle the inside of each cell.

The collector is shown on Plate VII, Fig. 2, just as it was mounted on the tractor. An AN connector was used to connect the leads from the bridge to the collector to facilitate removal and installation of the collector. Rubber connectors were used for transferring axle rotation to the collector to allow for non-alignment and to dampen vibrations.

Since the bridge circuit was designed to measure only the principal strain resulting from torque, the measured strain is a measurement of torque up to the elastic limit of the shaft metal if the calibration factor is known.

If the axle torque and rpm are known, horsepower being transmitted can be obtained.

The following formula shows the relationship:

$$\text{H. P.} = \frac{T\,n}{63{,}000}$$

where T = inch-pounds of torque

n = revolutions per minute

Electrical revolution counters were attached to measure the rear wheel revolutions; Plate VII, Fig. 2 shows one of them as it was attached to the collector shaft. The points in the counters made contact ten times per revolution of the counter shaft. Therefore the number of counts as recorded on the counter recorders was divided by ten to obtain the wheel revolutions.

Axle rpm was obtained by dividing the axle revolutions by the time taken, as recorded on a stop watch.

EXPLANATION OF PLATE VII

Fig. 1. Equipment and instrumentation layout for calibration of the tractor axle.

Fig. 2. The mercury bath collector and the wheel revolution counter tractor mounting.

PLATE XII

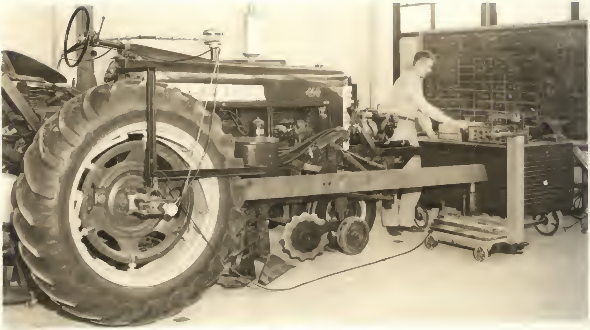


Fig. 1

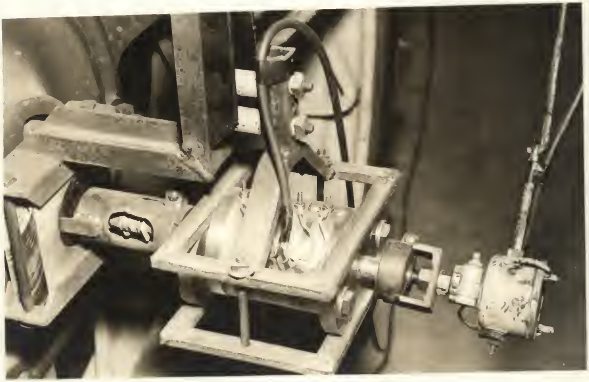


Fig. [illegible]

The average torque transmitted through the axle was obtained as follows.

1. The area in terms of square inches included between the torque curve and the neutral axis along the chart paper from the point at which the test started to where it was completed was obtained with a planimeter.

2. The base of the above area was measured in terms of inches.

3. The measured area was divided by the base length to obtain the average deflection in terms of inches. This value was multiplied by the number of chart lines per inch to obtain the average deflection in terms of lines.

4. The average deflection was multiplied by the attenuator setting to obtain attenuator lines. The attenuator line is equal to the measured strain in terms of micro-inches per inch. Torque in terms of inch-pounds was obtained by multiplying the strain by the calibration factor which was 88 inch-pounds per micro-inch.

Method for Measuring the Horsepower Requirement of the Till-Planter Tillage Units

The tillage unit linkage was set so that the straight portion of the tillage unit beam ran parallel to the surface while at operating depth. Therefore the draft required by each unit with exception of the draft required by the rolling coulter corresponded to the net force being transmitted by the beam at any point between the tool bar mounting plates and the point at which the beam curves down.

The section of the beam between these two points is subject to combined bending and tensile stresses under operating conditions.

Four A-5 strain gages were attached to this section of each beam; the gages were placed on the neutral axes of the beam on the top and bottom and each side of the beam. These four gages were attached at the same point along

the beam. Fig. 4 shows how these gages were wired together to form a single 120-ohm resistor for one of the legs of the Wheatstone bridge circuit. Since the top and bottom gages were wired in series, the strains due to bending in the vertical plane cancel out. The strains resulting from bending in the horizontal plane cancel out for the same reason. Therefore only strain resulting from tension is measured.

The three dummy gages that completed the bridge circuit were attached to a separate piece of steel; these gages were also 120-ohm A-5 gages. This piece was bolted on to the beam as shown by Plate VIII. The contact surfaces of the piece of steel and the beam were polished to increase the heat transfer rate. The purpose being that of keeping the dummy gages as near as possible to the temperature of the active gages, and thus provide temperature compensation.

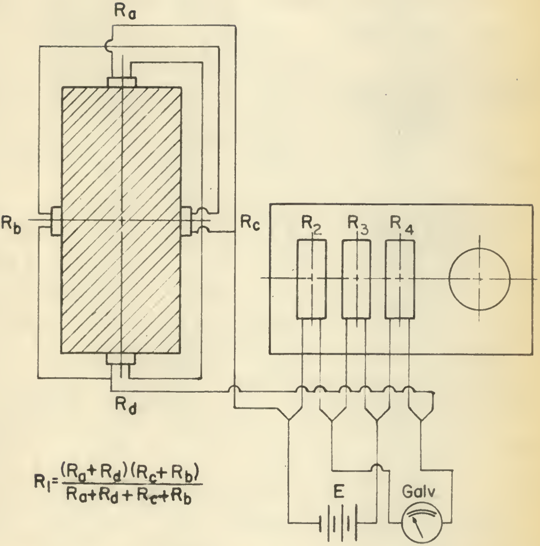
A shield made of plate steel completely surrounded the section of the beam where the strain gages were located. The shield was designed to fit as closely as possible to the beam; it slipped over the beam and was attached by the same bolts that attach the tool bar mounting plates.

A piece of rubber from a tire tube was wrapped tightly around the shield; it was secured on by wire loops.

The purpose of the shield and the shield cover was as follows:

1. To give the gages protection from mechanical damage.
2. To aid in keeping all of the gages at the same temperature.
3. To give the gages additional protection from moisture.

All of the gages were given two coats of Glyptal to seal out moisture. Glyptal is a resin-base dielectric material that is used in electric motor winding construction. It is tough and quite plastic upon air drying.



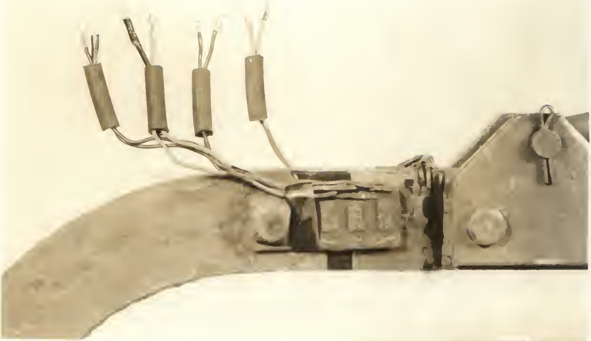
$$R_1 = \frac{(R_a + R_d)(R_c + R_b)}{R_a + R_d + R_c + R_b}$$

Fig. 4. Schematic wiring diagram of the bridge circuit used in measuring tillage unit draft with R_1 , R_2 , R_3 , and R_4 located within the bridge as they were in Fig. 2.

EXPLANATION OF PLATE VIII

The strain gage installation on one of the tillage unit beams. The three pairs of leads on the left extend from the dummy gages that are located on the bolt attached plate. The extreme right pair of leads are from the four-gage resistor unit of the beam. From right to left the resistors represented by the pairs of leads are R_1, R_2 , R_3 , R_4 , when referred to the basic bridge of Fig. 2.

PLATE VIII



The leads from each dummy gage and from the four-gage unit were made long enough to extend out of the shield. The advantages of making all of the connections outside the shield with brass bolts were as follows:

(1) The leads could be attached to each other and to the four-wire cable leading to the instruments without removing the shield.

(2) The active gage unit and a dummy gage could be used from each beam to form a bridge circuit that measured total draft without making solder connections or removing the shield.

(3) The steel plate on which the dummy gages were located could be removed without the use of a soldering gun. This was especially helpful in the calibration of the beams since the plate had to be removed.

(4) The chance for short circuits was minimized since the terminals were all outside the shield where they were not squeezed together.

When the active gages and the dummy gages are connected to form a Wheatstone bridge, as shown in Fig. 4, the strain of the beam due to draft can be measured. If the calibration factor is known, the measured strain is in effect a draft measurement up to the elastic limit.

If the draft and velocity of the beam are known the power requirement of the tillage unit can be obtained by the following formula:

$$H.\ P. = \frac{F \quad V}{33{,}000}$$

F = Draft in pounds

V = Velocity in feet per minute

The average draft for each test was obtained in the same manner as the average torque was obtained. The velocity was obtained by dividing the testing length in feet by the time in terms of minutes.

Torque Versus Strain Calibration of the Tractor Axle

Plate VI, Fig. 1 shows the setup for making the strain versus torque calibration on the axle of the Farmall 450. A 6⊔8.2 steel channel section beam was used to construct the lever.

The beam was bolted to the wheel on a line that intersected the centerline of the axle. The beam was extended to the front of the tractor, so that torque could be applied to the axle in the same manner as it would be under a normal load.

At a distance of eleven feet from the center line of the axle a small rod was welded on to the bottom edge of the beam, so that the applied force of a hydraulic jack would be concentrated at that point. The jack was supported on a scale so that the applied force could be measured. The tractor was jacked up, so that the right rear wheel would clear the ground. At this point the tare weight of the beam, the jack, and other necessary items was determined.

Leads from the collector were extended to a Brush amplifier; a Brush oscillograph was used to record the amplifier output. The amplifier was balanced and calibrated according to the manufacturer's operator instructions. The following formula appears in the instructions:

$$Kc = \frac{1}{SN} \frac{R}{F_m \ (Rc + R)}$$

Kc = the calibration constant

R = the resistance of each strain gage element

Rc = the calibration resistance (390×10^3 ohms)

N = the number of active gages

Fm = the gage factor

S = the sensitivity in micro-inches per inch per chart line

Any sensitivity can be assumed, but for matters of convenience one micro-inch per inch strain per chart line was chosen as suggested. This sensitivity is for an attenuator setting of one; when the attenuator setting is changed, the sensitivity changes to the same value as the attenuator setting in terms of micro-inches per inch of strain per chart line.

The Wheatstone bridge circuit from the axle had the following constants.

$$R = 500 \text{ ohms}$$

$$N = 4$$

$$Fm = 3.49$$

With the above constants substituted in the equation the value for Kc was found to be 91.72 attenuator lines.

Thus with the calibrate switch engaged, the pen deflection in terms of chart lines times the attenuator setting should always be equal to 91.72. An attenuator setting of five was used for calibration; this required a pen deflection of 18.34 chart lines.

After the balancing and calibration was completed the tractor brakes were locked, and torque was applied in increments of 1,100 foot-pounds. With the attenuator setting on 50, 1,100 foot-pounds of torque gave three lines deflection or 150 micro-inches per inch strain. Each additional 1,100 foot-pounds gave three lines additional deflection showing that the strain was linear with the applied torque. The torque was released in the same increments and the pen deflection again checked out at three lines per 1,100 foot-pounds.

Additional tests showed that the 150 micro-inches per inch strain per 1,100 foot-pounds of torque checked out each time.

From the following equation, which is obtained by equating two equations for shear stress in a round shaft, the theoretical principal strain can be calculated for a given torque.

$$= \frac{2T\,(1 + \mu)}{E\ r^3}$$

For the axle of the Farmall 450 the following values were assumed.

E for steel = 30×10^6 psi

Radius of Axle (r) = 1.375 inch

Poissions Ratio (μ) = .28

T = 13,200 inch-pounds

Since the calibration was made in terms of micro-inches per inch per 1,100 foot-pounds, a calculation was made to determine the theoretical principal strain resulting from 1,100 foot-pounds of torque.

By substituting the constants into the equation a value of 137.89 micro-inches per inch strain was found.

This value was slightly over twelve micro-inches per inch less than the value found from the calibration. However, this could be expected since the axle had two 1/4 x 5/8 inch keyways diametrically opposite the full length of the external part of the axle.

This reduced the effective diameter of the shaft slightly and caused an increase in principal strain per unit torsional shear.

Draft Versus Strain Calibration of the Tillage Unit Beams

The tillage unit beams were calibrated with a tensil testing machine. Therefore it was necessary to remove the beams from the tool bar. Equipment mounted on the beams also had to be removed.

Tension was applied to the straight portion of the beam. In order to accomplish this, a fork was constructed and attached to the beam at a point just ahead of the point at which the beam starts to curve. It was necessary to drill a hole on the neutral axis of the beam to provide a means for

attaching the fork.

The leads from the strain gages were attached as diagramed by Fig. 4, to form a Wheatstone bridge. The bridge circuit was connected to a Brush amplifier by a four-wire shielded cable. A Brush oscillograph recorded the strain gage signals.

The amplifier was balanced and calibrated just as it was for the axle calibration. The values for calculating the calibration constant were different and they were as follows:

R = 120 ohms (gage resistance)

F = 1.98 (gage factor)

N = 1 (number of active gages)

Substituting the above constants into the formula for the calibration constant results in a value of 155 attenuator lines for Kc.

Thus, with the calibrate switch engaged the pen on the oscillograph showed 15.5 lines deflection when the attenuator was on a setting of ten.

Tension was applied to the straight portion of the beam in increments of 1000 pounds up to 8000 pounds. The chart was marked at the exact time that the tensil testing machine indicated each 1000-pound increment.

Figure 5 shows the curves for beam deflection versus tension for each beam.

The center curve was obtained by averaging the deflections for the two beams and plotting the values just as was done for each beam. This curve was used in obtaining the calibration constant when the total deflection of both beams was measured by a single Wheatstone bridge. The wiring diagram for this arrangement is shown by Plate IX.

The maximum error that could occur when the total deflection of the two beams was being measured by one bridge would be the case when one beam was

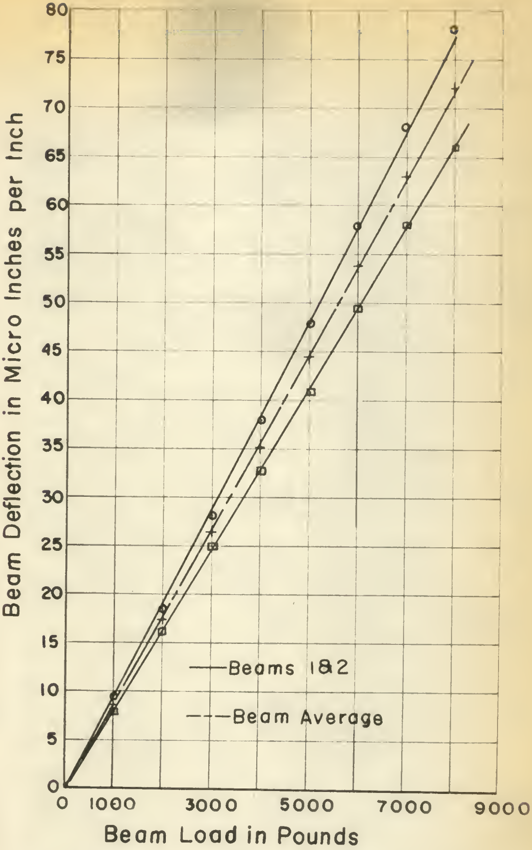
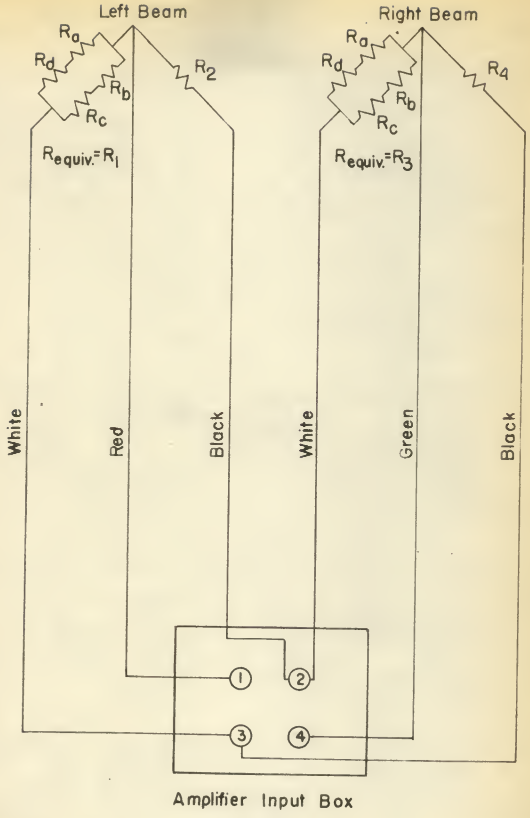


Fig. 5. Micro-inches of deflection versus tillage unit beam load in pounds.

EXPLANATION OF PLATE IX

Schematic wiring diagram of the Wheatstone bridge circuit utilized for measuring the total draft of the tillage units. The active gage unit and one dummy gage were used from each beam to form a single bridge with two active legs. Three of the four wires from each of the lead cables were used to extend the bridge halves to the amplifier input box where the final connections were made to complete the bridge circuit. R_1, R_2, R_3, and R_4 are located within the bridge as in Fig. 2.

PLATE IX


Left Beam
Right Beam
R_a
R_b
R_c
R_d
R_2
R_4
$R_{equiv.} = R_1$
$R_{equiv.} = R_3$
White
Red
Black
White
Green
Black
1
2
3
4
Amplifier Input Box

under load when the other was not. The error varies from 10 per cent at 1000 pounds to 7.5 per cent at 8000 pounds. Tests run with the deflection from each beam recorded separately showed that the draft requirement for each beam was nearly the same for most tests. Therefore the error involved should be relatively small when total draft is measured by a single bridge.

Instrumentation Installation

The instruments and the instrument operator were carried on a platform located to the rear and slightly above the tractor operator as shown by Fig. 6.

Figure 7 shows the plywood cabinet that was constructed to house the instruments. The amplifiers and the recorder were set on plywood platforms; recesses in the platforms were made for the rubber feet of amplifier and recorder to immobilize the units on the platform. The platforms were made smaller than the compartments so that foam rubber blocks could give lateral as well as vertical damping from jars and vibrations. The wheel-revolution counter recorders and the counter switch were located on a panel which was attached on the back of the oscillograph compartment.

The vertical wire that is shown attached to both amplifiers grounded both amplifiers to the tractor. This method of grounding prevents ground loops, which sometimes cause 60-cycle alternating signals to be picked up.

Four-conductor shielded wire was used to connect the bridges to the amplifiers. The shield was grounded at the amplifier and left open circuited at the bridge end as recommended.

The bottom amplifier is shown as it was employed to take the strain signals from both beams. The active gage unit and a dummy gage were used from each beam. The bridge circuit for this arrangement was mentioned in a previous section and the circuit diagram is shown by Plate IX.

Fig. 6. The tractor as it was equipped for till-planter power requirement testing.

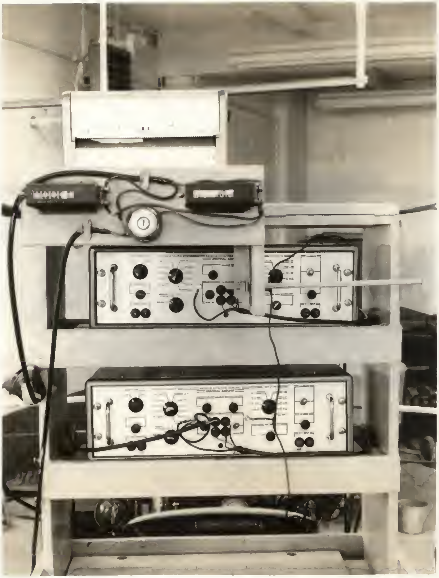


Fig. 7. The plywood instrument cabinet and the instruments used in the power requirement tests.

Carrying the instruments and the instrument operator on a tractor mounted platform provided advantages over the use of an additional vehicle for this purpose. These are as follows:

1. The most obvious is that of eliminating the need for the vehicle and the operator.

2. The tractor is more mobile.

3. The instrument operator is close to the tractor operator, thus simplifying communication.

Several disadvantages were noted, and these are as follows:

1. The instruments were more subject to vibrations and jars; this was true even though the instruments were supported by foam rubber blocks.

2. The platform, instruments, and the operator added considerable weight to the rear wheels of the tractor while decreasing the weight on the front wheels.

The first listed disadvantage could be alleviated by improving the design of the amplifier and recorder mountings. A representative of the Brush Electronics Company suggested the use of war surplus aircraft instruments mountings for this purpose.

The additional weight added that was referred to as the second disadvantage was not of any consequence to the power requirements measurements that were made since a high degree of accuracy was not needed.

No previous mention has been made about the power source for the strain gage instrumentation. A 120 volt, 500 watt, alternating current, engine-driven generator was employed for this purpose. It was mounted on a frame that extended out in front of the tractor. The purpose of mounting the power unit in front was to place it as far as possible from the instruments to minimize signal pickup from it.

Field Testing Procedures

1. The testing area was chosen where the slope of the terrain was as gentle and uniform as possible.

2. Six stakes were driven in the ground at the edge of the test area to define three 100-foot test lengths, spaced with 40-foot intervals between test lengths. Six additional stakes were driven in the soil on a line approximately perpendicular to the first row and at a distance of 25 feet to one side of each stake.

3. Several trial runs were made to make depth adjustments that were necessary to keep the outside cutting tip of the upper sweep operating at a one to two-inch depth. This was accomplished by adjusting the stop collars on the depth control cylinders.

4. Three replications were made for each testing speed, and tests were made at three speeds for each test series. The following power requirement test series were conducted on each of the three test sites.

a. Tests with the tillage units equipped with the original sweeps.

b. Tests with the tillage units equipped with the original sweeps and the repositioned lower sweeps.

c. Tests with the tillage units equipped with the modified upper sweeps.

d. Tests with the tillage units equipped with the modified upper sweeps and the repositioned lower sweeps.

All of the above tests were made in one direction; if a slope existed, the tests were run down slope.

5. The following data were recorded for each test:

a. The strain in the tillage unit beams from the draft and the strain due to torque on the right rear axle were recorded on two channels

of a Brush oscillograph. The two amplifiers were calibrated in the same manner as has been described. A calibrate switch was used to mark the beginning and end of each test. This was done as the two stakes at the ends of each test length lined up visually.

b. The time taken for each test was recorded on a stop watch; the stop watch was started and stopped as the two stakes at the end of each test length lined up visually.

c. The switch for the counters was turned off and on at the same time as the stop watch was started and stopped. Therefore the counter recorders indicated the rear wheel revolutions turned for each test.

Several power requirement tests were made to determine the power consumed by the planter alone. The following procedure was employed:

1. The desired number of runs were made the full length of the test area with the tillage units operating normally. The planter unit was not operated and the data was not taken.

2. Part of the previously tilled runs were traversed again with the planter unit operating, and the tillage units raised. Axle torque, wheel revolutions, and time were recorded as in the procedure previously defined.

3. The remaining tilled runs were traversed with all components raised; data were taken as above.

Power Requirement Test Results

Testing Site Descriptions. Power requirement tests were conducted in three test areas in accordance with the procedures set forth in the preceding section.

The testing areas were chosen so that each was of a different soil type.

The purpose being that of determining how the power required by the till-planter varied in three different soil types.

Particle size analysis, liquid and plastic limit, moisture percentage, and bulk density tests were made for each soil type. Table 4 summarizes the results.

Table 4. Summary of soil test results from the three test sites.

Soil Class	Per cent clay	Per cent silt	Per cent sand	Plastic limit	Liquid limit	Moisture Content Depth	Moisture Content Percent	Bulk Density Depth	Bulk Density gm/cc
Silty clay	45.0	49.0	6.0	25.2	42.0	0-3"	19.4	0-3"	1.36
						3-6"	21.9	3-6"	1.42
						6-9"	23.5	6-9"	1.40
Clay	60.0	38.0	2.0	27.3	54.7	0-3"	24.3	0-3"	1.27
						3-6"	31.4	3-6"	1.31
						6-9"	31.1	6-9"	1.32
Loam	20.0	48.0	32.0	---	23.7	0-3"	13.4	0-3"	1.40
						3-6"	14.5	3-6"	1.43
						6-9"	14.9	6-9"	1.45

The particle size analysis tests were made by the hydrometer method. The clay, silt, and sand percentages are based on the U. S. Bureau of Soils System in which clay is defined as percentage of particles smaller than two microns, and silt is defined as percentage of particles in the range of .002 to .05 millimeters in diameter.

The power requirement measurements were made during October and November of 1958. Tillage that had been done on the test sites previous to testing varied.

A wheat crop had been harvested from the silty clay soil test site the summer immediately preceding the tests. A thick growth of volunteer wheat existed on the soil surface at the time of the tests. Harvesting had been accomplished under wet soil conditions. Therefore the soil was in a tough

condition when the tests were made since the soil had not been disturbed between harvesting and testing.

The clay soil test area had been fallowed the summer immediately prior to testing; however, it was in a very tough condition due to the nature of the soil and the high rainfall of the summer. The area was very poorly drained; so the necessary tillage had not been accomplished to keep weed growth down. In all probability tillage accomplished was done at a high soil moisture content. The top three inches of soil was very hard and run together; soil beneath this layer was very wet as Table 4 shows.

The loam soil test area had had a milo crop harvested from it just prior to testing. The milo had been planted immediately following a wheat harvest, so it was the second crop harvested from the field for the year. The harvesting of the milo was accomplished under wet soil conditions. Therefore the effects due to previous tillage may have been decreased a great deal.

<u>Testing Data Calculations</u>. Data were taken as previously outlined. Calculations were made for the following:

1. Rpm and per cent slip of the right rear tractor wheel.
2. The average torque being transmitted by the right rear axle.
3. The average horsepower being transmitted by both axles.
4. The horsepower as measured above minus the horsepower lost to slip.
5. The total average draft of the tillage units.
6. The velocity in terms of feet per minute.
7. The average horsepower consumed by the tillage units.

The average torque, rpm, horsepower transmitted by the axle, draft, velocity, and tillage unit draft for each test were obtained as outlined in the previous sections on methods.

The average horsepower being transmitted through both axles for each test will be referred to as the axle horsepower. This value was obtained by doubling the calculated value of average horsepower transmitted by the right axle. This was possible for two reasons, which are as follows:

1. As mentioned previously, the torque should be of the same magnitude in both axles.

2. The axle revolutions per test did not vary significantly.

The per cent slip was calculated for each test from a form of the following per cent slip formula:

$$\text{Per cent slip} = \frac{\text{Advance per wheel revolution with no pull} - \text{Advance per revolution with pull}}{\text{Advance per revolution with no pull}}$$

Repeated tests showed that the wheels made 6.9 revolutions while traversing the 100-foot test length without any load.

The formula was adapted so that the per cent slip could be calculated from the wheel revolutions turned for each test. The following formula was used:

$$\text{Per cent slip} = \frac{\text{Wheel revolutions per 100 foot test} - 6.9}{\text{Wheel revolutions per 100 feet}}$$

The average horsepower lost due to slip was found for each test by multiplying the axle horsepower by the per cent slip. The axle horsepower minus the slip horsepower represented the power consumed by the till-planter as a whole and the tractor rolling resistance. This difference will be referred to as the available axle horsepower.

The power consumed by the rolling coulters was not included in the tillage unit draft measurement. This was due to the fact that the rolling coulters were attached to the front portion of the beams. Therefore the difference between the available axle horsepower and the tillage unit

horsepower represents the horsepower consumed by the planter unit, the tractor rolling resistance, and the rolling coulters.

Figures 8, 9, and 10 show axle, available axle, and tillage unit horsepower versus velocity curves for the three soils.

The dynamic nature of the soil and a possible variation in operating depth caused some rather wide variations. The relationship between horsepower and velocity appeared to be linear; this was rather logical since neither the draft of the tillage units, nor the axle torque appeared to increase with velocity.

The various test series did not show any consistent trend for either an increase or a decrease in tillage unit horsepower. If differences existed they were evidently overbalanced by the variable nature of the soil. An increase in draft was expected for the modified sweep, as has been mentioned.

The axle, available axle, and tillage unit horsepower versus velocity plottings were obtained from the entire data from each test site.

Since a linear relationship was assumed for horsepower versus velocity, linear regression statistical methods could be applied to determine the slope of the curve and to locate the curve. The sample regression equation of Y on X is written as follows:

$$Y - \bar{y} = b\,(X - \bar{x})$$

where

$$\bar{y} = \frac{\Sigma Y}{n}$$

$$\bar{x} = \frac{\Sigma X}{n}$$

n = number of tests
b = sample regression coeficient

The sample regression coeficient is the slope of the line. The procedure for finding the regression coeficient is as follows:

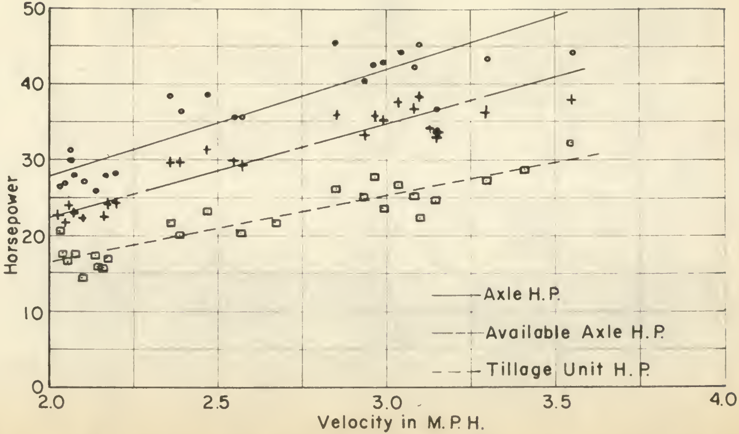


Fig. 8. The axle, available axle, and the tillage unit required horsepower versus speed curves for the clay soil.

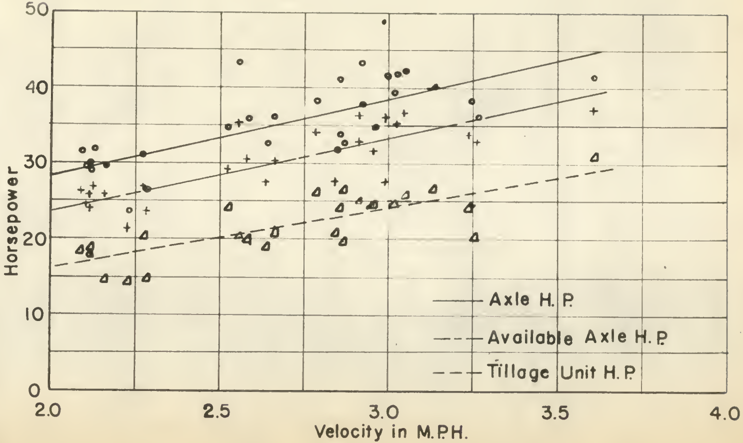


Fig. 9. The axle, available axle, and the tillage unit required horsepower versus speed curves for the silty clay soil.

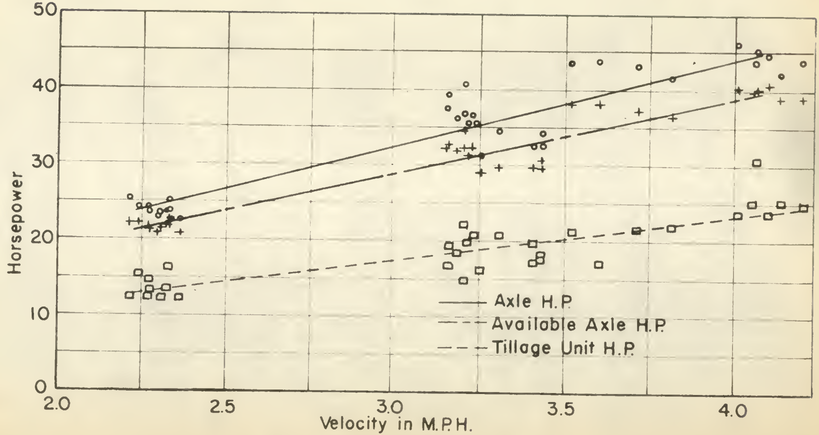


Fig. 10. The axle, available axle, and tillage unit required horsepower versus speed curves for the loam soil.

$$b = \frac{\Sigma x y}{\Sigma x^2}$$

where $\Sigma x y = \Sigma X Y - \frac{\Sigma X \Sigma Y}{n}$

$$\Sigma x^2 = \Sigma X^2 - \frac{(\Sigma X)^2}{n}$$

The use of the regression formula may be employed to predict a value of Y for any given value of X. The value of Y obtained by substituting a value of X in the regression formula is an average value. The variance, s_y^2, of a randomly selected X must be obtained to predict a range of Y for a given X. The variance was obtained from the following equations:

$$S_{y \cdot x}^2 = \frac{\Sigma y^2 - \frac{(\Sigma x y)^2}{\Sigma x^2}}{n - 2}$$

$$S_Y^2 = S_{yx}^2 \left(1 + \frac{1}{n} + \frac{x^2}{x^2}\right)$$

where

$$\Sigma y^2 = \Sigma Y^2 - \frac{(\Sigma Y)^2}{n}$$

$$\Sigma x^2 = \Sigma X^2 - \frac{(\Sigma X)^2}{n}$$

$$\Sigma xy = \Sigma XY - \frac{(\Sigma XY)^2}{n}$$

n = sample size

$X = X - \bar{x}$

$$\bar{x} = \frac{\Sigma X}{n}$$

For any value of X the range that could be expected for Y was as follows:

$$Y - t_{.05} S_Y \leq \mu \leq Y + t_{.05} S_Y$$

where

Y = the point estimate of μ

$t_{.05}$ = the value found from t distribution tables with .95 confidence limits.

S_Y = the variance at the point estimate.

In making calculations from the test data to determine ranges of horsepower that could be expected for any given velocity, the preceding equations were utilized with X as the velocity in feet per minute and Y as axle, available axle, or tillage unit horsepower.

The formulas that were obtained are summarized in Table 5.

Table 5. Sample regression and variance formulas obtained for axle, available axle, and tillage unit horsepower versus velocity in feet per minute.

Soil	Horsepower	Number of tests	$t_{.05}$	Regression Formula	Variance Formula
Clay	Axle	29	2.052	HP = .1589V + .10	$S^2 = 14.06 + \frac{V^2}{3682}$
	Available Axle	29	2.052	HP = .1383V - 1.78	$S^2 = 5.031 + \frac{V^2}{9947}$
	Tillage Unit	30	2.048	HP = .097V - 4.20	$S^2 = 3.464 + \frac{V^2}{14,444}$
Silty Clay	Axle	38	2.029	HP = .1168V + 7.76	$S^2 = 11.521 + \frac{V^2}{4549}$
	Available Axle	38	2.029	HP = .1108V + 4.07	$S^2 = 6.145 + \frac{V^2}{8529}$
	Tillage Unit	38	2.029	HP = .0895V + .47	$S^2 = 5.657 + \frac{V^2}{9265}$
Loam	Axle	35	2.032	HP = .1282V - 1.35	$S^2 = 8.105 + \frac{V^2}{15946}$
	Available Axle	35	2.032	HP = .1123V - .75	$S^2 = 4.219 + \frac{V^2}{30.63}$
	Tillage Unit	35	2.032	HP = .0669V - .26	$S^2 = 5.240 + \frac{V^2}{24667}$

The ranges of axle, available axle, and tillage unit horsepower that can be expected from the three soil types under similar conditions are summarized in Table 6 for several velocities.

Table 6. Expected ranges of horsepower required by the till-planter at several speeds.

Velocity: M.P.H.	Horsepower	Soil Type: Clay	Silty Clay	Loam
2.0	Axle	18.21 - 33.91	21.22 - 35.42	15.20 - 27.22
	Available axle	17.86 - 27.26	18.38 - 28.76	14.68 - 23.36
	Tillage unit	12.75 - 20.55	11.24 - 21.20	6.67 - 16.35
2.5	Axle	27.36 - 42.76	26.58 - 40.34	20.99 - 32.71
	Available axle	24.05 - 33.25	23.41 - 33.49	19.73 - 28.19
	Tillage unit	17.13 - 24.71	15.33 - 24.99	9.76 - 19.16
3.0	Axle	34.24 - 49.84	31.65 - 45.55	26.71 - 38.27
	Available axle	30.07 - 39.39	28.25 - 38.39	24.73 - 33.07
	Tillage unit	20.31 - 28.07	19.23 - 28.97	12.75 - 22.05
3.5	Axle	40.88 - 57.20	36.50 - 50.96	32.33 - 43.93
	Available axle	35.91 - 45.73	32.92 - 43.48	29.67 - 38.01
	Tillage unit	25.40 - 33.52	22.97 - 33.11	14.70 - 24.00
4.0	Axle	--- ---	--- ---	37.88 - 49.68
	Available axle	--- ---	--- ---	34.53 - 43.03
	Tillage unit	--- ---	--- ---	17.55 - 28.73

Axle Horsepower Required. Figure 11 shows axle and available axle horsepower versus velocity curves for the three soils. The maximum power that the tractor would develop and slip were the factors that limited the speed to slightly over three mph in the silty clay and clay soils and to slightly over four mph in the loam soil. The maximum axle power developed appeared to be

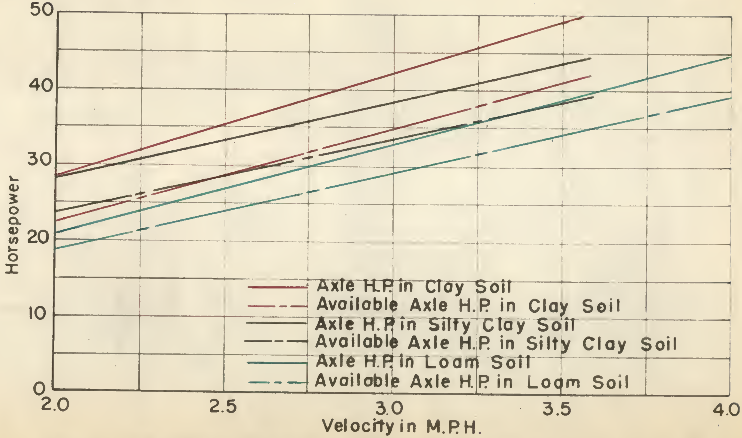


Fig. 11. The axle and available axle required horsepower versus speed curves for the three soils as reproduced from Figures 8, 9, and 10.

approximately 45 horsepower. This value checked out closely with the maximum corrected horsepower that the tractor would develop from the power take-off shaft as recorded by a M - W Hydra gage dynamometer.

The axle horsepower requirements in the clay and silty clay soils appeared to be about the same initially. However, as the speed was increased, the axle power requirement increased at a faster rate in the clay soil. This is logical because the clay soil contained more colloidal and moisture content at the time of the tests. Slippage was also greater in the clay soil, resulting in more power loss.

The reason for the axle power requirement in the loam soil to increase at nearly the same rate as in the silty clay soil is harder to justify. Evidently it is due to a greater increase in the tractor rolling resistance with an increase in the speed in the loam soil. The tillage unit power requirement curves show quite the opposite effect. Figure 12 shows the curves of the three soils for tillage unit horsepower versus speed. Here it can be observed that the tillage unit horsepower increases at a higher rate with speed in the silty clay soil than it does in the loam soil. This effect must have been balanced by the greater increase in rolling resistance power consumption in the loam soil.

The axle horsepower required by the till-planter at three mph will probably range from 27 to 50 horsepower for most Kansas soils.

The expected range is 32 to 57 horsepower at 3.5 mph. Values for other speeds can be obtained from Table 6.

This range was determined from the following assumptions:

1. Two extremes were represented in the soil types; therefore the axle power required in most soils should be included in this range.

2. The clay soil was in a condition similar to what might be

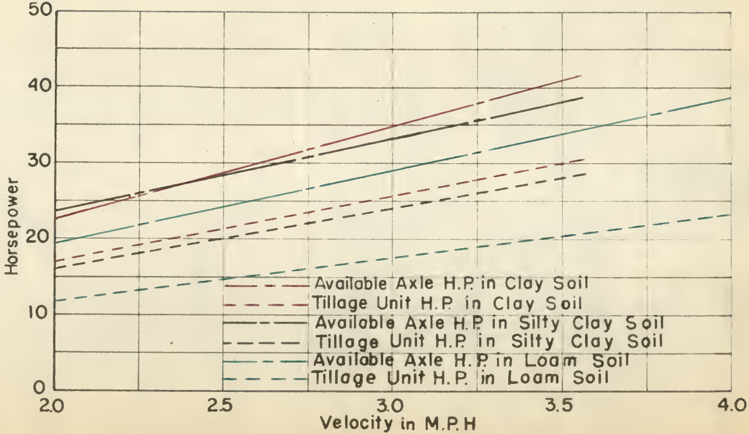


Fig. 12. The available axle and tillage unit required horsepower versus speed curves for the three soils as reproduced from Figures 8, 9, and 10.

expected in the spring at the time when most row crops are planted. It was tough and at a moisture percentage almost equaling its plastic limit.

3. The loam soil might have been a little drier than what might be expected at spring planting times. However, the moisture content does not affect the power requirement of tillage implements to much of an extent in soils having a low clay content as has been mentioned.

The above defined range would probably vary considerably with various tractors. Tire size, wheel weighting, and several other factors would cause the range to vary for a given tractor.

Available Axle Horsepower. Figure 11 shows the axle and the available axle horsepower versus speed curves for three soils.

Available axle horsepower was obtained by subtracting the horsepower lost due to slip from the axle horsepower. Therefore it represents the power required by the complete till-planter and the tractor rolling-resistance.

The spread between the curves was reduced for available axle horsepower as compared to axle horsepower. This is only natural since the per cent slip was quite low in the loam soil and quite high in the clay soil.

The rate of change of available axle horsepower with increased speed was less in each of the soils when compared with the respective rate of change of axle horsepower with increased speed. This was due to an increased horsepower loss due to slip when the speed was increased.

The expected available axle horsepower required by the till-planter in various soils would range from 25 to 39 horsepower at three mph and 29 to 46 horsepower at 3.5 mph, according to the regression variance analysis and the assumptions mentioned in the previous section. Expected horsepower ranges are given for other velocities in Table 6.

Tillage Unit Horsepower Required. Available axle and tillage unit required horsepower versus speed curves are shown in Fig. 12.

The horsepower difference between available axle horsepower and the tillage unit horsepower for each soil represents the power required by tractor rolling resistance, the planter units, and the tillage unit rolling coulters.

The available axle and the tillage unit horsepower versus speed curves show that the horsepower rate of increase with speed was greater for available axle power, thus showing that the power consumed by the tractor rolling resistance, the planter units and the rolling coulters increased with speed. The most notable increase occurred in the loam soil. Little doubt exists but that the large increase was due mainly to a large increase in tractor rolling resistance with speed. It is highly improbable that the increase would be due to a large increase in required horsepower of the planter units and the rolling coulters with speed because the same characteristic would have shown up more in the heavier soils.

The tillage unit horsepower in the three soils consumed 50 to 63 per cent of the axle horsepower. The low percentage was in the loam soil and the high percentage was in the silty clay soil. The tillage unit horsepower in the clay soil was in the upper part of the range being approximately 58 per cent.

The horsepower range that can be expected in most soils by the tillage units neglecting the power required by the rolling coulters appears to range from 13 to 29 horsepower at three mph and 20 to 35 horsepower at 3.5 mph. These values were obtained from Table 6, the previously mentioned assumptions were made.

Planter Horsepower Required. Several separate power requirement tests were made for the rear-mounted planter in the three soils. The procedure that

was employed in making these tests is outlined in the section on field testing.

This method was not successful for determining the horsepower required by the planter for the following reasons.

1. The front wheels of the tractor had to be operated on the ridge of the previously tilled rows, causing a variation in the power required to drive the tractor.

2. The horsepower required for driving the tractor was relatively large when compared to that of the planter unit.

Since the horsepower required by the planter appeared to range from only two to three horsepower in the three soils, any small variation in the power required to drive the tractor caused a large percentage in error for the planter power measurement.

Therefore no effort was made to obtain enough data for a planter horsepower versus speed curve for each soil.

SUGGESTIONS FOR FURTHER INVESTIGATION

The crop experimentation completed under this investigation was just a start; one year's results are not adequate. The crop experimentation should be conducted over a period of several years; other minimum tillage methods should be included also.

Soil erosion studies should be made to determine the soil loss from till-planted row crops as compared to soil loss from other methods of planting. Water run-off studies could be made at the same time.

Lister type of cultivation equipment mixes the crop residues into the soil too much when used on till-planted row crops. An investigation should be made towards the development of equipment that will give good weed and grass

control and will leave the crop residue on the surface where it can give maximum protection.

A rear mounting of the complete till-planter could provide some good advantages. It would give more weight transfer to the rear wheels, and it would also eliminate the loose soil being moved out ahead of the rear wheels. Mounting could be made simpler; the whole implement could be mounted on a tool bar. Some of the component parts are too bulky to use in their present form for a complete rear mounting. A specially designed planter would be needed to reduce the overall length. The rotary-hoe units could be mounted closer to the sweep units to further reduce the length.

The economics of the till-planter method of planting row crop as compared to other conventional tillage and planting methods deserves investigation. The till-planter is an expensive implement. Certainly the farmer is going to want to know whether or not the additional expense will give him enough additional net profit to justify the investment.

The draft of the till-planter is quite high for only a two-row operation. Perhaps a rear mounting would reduce the power consumed by slip and rolling resistance. Since most of the overall power is consumed by the tillage units, an investigation should be conducted for the purpose of decreasing the draft without sacrificing for a poorer seedbed preparation. By recording the draft on each of the tillage units new designs of sweeps and various other modifications could be tried on one of the units; the other unit could remain standard. By this method, a comparison could be made and many of the variable effects would be greatly reduced.

SUMMARY OF RESULTS

The planting of corn in alfalfa sod with the till-planter proved rather impractical. The clogging of alfalfa growth between the sweep units caused excessive stoppage. The power required was excessive; the tillage units did not kill the alfalfa sufficiently. The alfalfa grew up between the rows in a matter of a few weeks. The Simazon spray did not seem to affect the alfalfa growth.

Little difficulty was encountered in planting the till-planter corn plots at the Belleville Experimental Station and the Courtland Irrigation Experiment Field. The clogging of the rotary-hoe wheels with packed soil gave the most trouble. This was eliminated in later plantings by the removal of the culti-packer wheels.

Weed control was the poorest in the till-planter plots. Most of the weeds were located in the undisturbed four-inch strip left by the upper sweeps. These weeds became large before cultivation was accomplished; so the cultivation would not cut them out effectively. Weed control in the row appeared to be good. Little difference, if any, could be observed between the weed population in the sprayed and unsprayed till-planter plots. However, quite the reverse was true in the sorghum plots. Heavy rains possibly leached the Simazon out of the soil surface on the corn plots.

The rate of growth of the till-planter corn nearly equaled that of surface-planter corn. It was well ahead of the listed corn during the early part of the summer. By the end of July, little if any, difference could be observed between any of the plots.

A statistical analysis of the corn yields did not show any significant differences in yield due to the method of planting at the five per cent level.

A possible reduction might have been expected from till-planting since the growing season was abnormally wet. Mulch tillage favors drier conditions according to research that was referred to in the review of literature.

Chinch bug infestation caused wide variations in the milo plots. The listed milo got a good start and did not seem to be affected by the chinch bugs. The other plots were badly retarded by them. This effect gave the listed milo a yield that was significantly better than any of the other methods. The Simazin spraying proved detrimental to milo: the sprayed plots were stunted and gave yields significantly lower than any of the other planting methods; however, the weed control was excellent.

The till-planter has quite a potential for use in the double-cropping system. However, the lister also lends itself well to row-crop planting following a grain harvest. Listing can also be accomplished in stubble without prior tillage. The advantages of the till planter over listing that were noted were as follows:

1. Heavier rates of fertilizer can be applied simultaneously with planting with the till-planter.

2. The till-planter leaves more of the crop residue on the surface where it can protect the soil.

The till-planter would not operate very well in a wet loose soil. A modification of the upper sweep corrected this difficulty. The modification afforded the sweep units more downward force from the soil reaction without tipping the whole sweep unit forward.

Till-planter power requirement tests were conducted in the three following soils: a light loam soil, a silty clay soil, and a clay soil. Since two extreme soils were represented in the soil types, it was assumed that the power requirements in these two soils would give the extremes for required

axle, available axle, and tillage unit horsepower for most soils.

The relationship between horsepower and velocity appeared to be linear, therefore linear regression statistical methods could be used to locate the curves. The horsepower standard errors were calculated for several velocities so that expected ranges of horsepower could be set for the respective velocities in each soil.

Since two extreme soils were represented and the extreme expected values for each soil were known, ranges of expected required horsepower for most soils could be set for several velocities. These ranges were defined by the maximum expected power required in the clay soil and the minimum power expected in the loam soil for given speeds.

The range of horsepower required at the rear wheels that could be expected for most soils was from 32 to 57 horsepower at 3.5 mph. The range was reduced to 29 to 46 horsepower when power lost to slippage was subtracted from the total. The range that could be expected by the tillage units alone at 3.5 mph was from 20 to 35 horsepower.

The ranges for other speeds are listed in Table 6.

Rear-wheel slippage was quite high. It ranged from a low of eight per cent to a high of 24 per cent for all of the individual tests. Slip appeared to be independent of speed. The average slip on each soil was 11.00, 14.45, and 17.43 per cent for loam, silty clay, and clay soils respectively.

The overall results of this investigation showed that the till-planter had advantages and disadvantages when compared with conventional tillage and planting methods. The major advantages noted were as follows:

1. The ground surface is protected by crop residue up to the time of planting.

2. Most of the crop residues are left on the surface between the rows following planting.

3. The number of trips over a field is reduced since pre-tillage is unnecessary.

4. Heavier rates of fertilizer can be applied simulteneously with planting since a portion is distributed five inches beneath the planting depth.

Disadvantages noted were as follows:

1. Planting is delayed under wet conditions since a mulch-covered soil dries out more slowly.

2. When the planting is delayed, the weeds get a good start; those left by the upper sweeps are very hard to cut out with a cultivator.

3. Planting is slower with the till-planter; a tractor that can operate a four-row lister can only handle a two-row till-planter.

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LITERATURE CITED

1. Aldrich, S. R.
   New styles in seedbeds. Crops and Soils, November, 1956, 9:12-15.

2. Brim, C. A. and H. W. Johnson.
   This land is kept busy growing two crops a year. What's New in Crops and Soils, December, 1955, 8:18,21.

3. Browning, G. M.
   Principles of soil physics in relation to tillage. Agr. Engg., July, 1950, 31:341-344.

4. Browning, G. M. and R. A. Norton.
   Tillage practices on selected soils in Iowa. Soil Sci. Soc. Amer. Proc., 1945, 10:461-468.

5. Burrough, D. E.
   Power and torque distribution in farm machine drive shafts. Agr. Engg., June 1953, 34:382-384.

6. Clyde, A. W.
   Measurement of forces on soil tillage tools. Agr. Engg., January, 1936, 17:5-9.

7. Clyde, A. W.
   Technical features of tillage tools. Pennsylvania Agr. Ext. Sta. Bulletin 465, 1944.

8. Duley, F. L.
   Surface factors affecting the rate of intake of water by soils. Soil Sci. Soc. Amer. Proc., 1939, 4:60-64.

9. Duley, F. L. and J. C. Russell.
   Crop residues for protecting row crop land against runoff and erosion, Soil Sci. Soc. Amer. Proc., 1941, 6:484-487.

10. Duley, F. L. and J. C. Russell.
    Effect of stubble mulching on soil erosion and runoff. Soil Sci. Soc. Amer. Proc., 1942, 7:77-81.

11. Harrold, L. L.
    Soil loss as determined by watershed measurements. Agr. Engg., March, 1949, 30:177-180.

12. Hines, R. C., Jr., J. H. Lillard, and L. W. Edminster.
    Applying stubble mulch tillage in Virginia. Agr. Engg., November 1947, 28:507-508.

13. Jenson, James H.
    Experimental stress analysis. Agr. Engg., September, 1954, 35:625-629.

14. Lowdermilk, W. C.
Conquest of the land through seven thousand years. Agr. Information Bulletin 99. 1953.

15. Nichols, M. L.
Soil compaction by farm machinery. Soil Conservation, December, 1957.

16. Nichols, M. L. and C. A. Reaves.
Soil structure and consistency in tillage implement design. Agr. Engg., August, 1955, 36:517-520.

17. Perry, C. C. and H. R. Lessner.
Strain gage primer. New York. McGraw-Hill Book Company, Inc., 1955. 281 p.

18. Page, J. B., C. J. Willard, and G. W. CcCuen.
Progress report on tillage methods in preparing land for corn. Soil Sci. Soc. Amer. Proc., 1947, 11 (1946): 78-80.

19. Randolph, John W. and I. F. Reed.
Test of tillage tools. Agr. Engg., January 1938, 19:29-30.

20. Reed, I. F.
Some factors affecting design of tillage machinery and proposed approach to their evaluation. Soil Sci. Soc. Amer. Proc., 1945, 9 (1944):233-235.

21. Scarseth, George D.
Corn every year without a plow. Farm Journal, March, 1956.

22. Scarseth, George D.
No substitute for efficiency. The Nations Agriculture, February, 1958. pp. 12-13 and 22.

23. Schaller, F. W. and D. D. Evans.
Some effects of mulch tillage. Agr. Engg., October, 1954, 35:731-734.

24. Schoenleber, L. H.
Strain gages and stresscoat in machinery design. Agr. Engg., May, 1955 36:309-317.

25. Telischi, Baba, H. F. McColly and Earl Erickson.
Draft measurement for tillage tools. Agr. Engg., September, 1956, 37:605-608.

INVESTIGATION OF THE PERFORMANCE OF THE
I. H. C. 4M - 21 TILL PLANTER
FOR KANSAS AGRICULTURE

by

STANLEY JOE CLARK

B. S., Kansas State College
of Agriculture and Applied Science, 1954

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

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1959

The purpose of the investigation was to find out as much as possible in one year about the overall performance of the I. H. C. 4M-21 till-planter for Kansas agriculture.

The following methods of planting corn were made for purposes of trying to determine advantages and disadvantages of the till-planter as compared to other methods utilized in the tests:

1. Till-planter with Simazin pre-emergence spray.
2. Till-planter without spray.
3. Lister.
4. Surface-planter.

The various plantings were made in randomized test blocks that were replicated either four or five times.

During the first part of the growing season differences in plant growth could be noted, but they disappeared soon after the corn had all tasselled.

All the plots received the same number of cultivations. Weed control was the poorest in the till-planted plots; weeds were just about as thick in the sprayed plots. However, most of the weeds were located in the center of the row in the four-inch strip that the till-planter upper sweeps left.

A statistical analysis of the yields showed no significant difference in yields due to planting method at the five per cent level.

The same experiment was made on milo; a chinch bug infestation proved to be more of a variable than the method of planting. However, it was concluded that the Simazin spray was detrimental to milo. A statistical analysis showed that the average yield for the sprayed plots was significantly lower than any of the other yields.

The till-planter was utilized in a wheat-soybean and a wheat-milo double-cropping system to determine the potential of the till-planter for this use.

A great deal of stoppage due to clogging of straw residue was encountered; an upper sweep modification almost eliminated this difficulty. Yield data was not taken, but the overall observations made showed that the till-planter has good possibilities for use in the double-cropping system.

Strain gage equipment was utilized in performing power requirement tests for the till-planter. The complete instrumentation was mounted on the tractor. SR-4 strain gages were attached to the tillage unit beams and to the right rear axle to measure the draft of the tillage units and the total axle torque respectively. A mercury bath collector was constructed and used to transfer the rotating circuit of the axle into a stationary circuit.

Brush analyzing equipment was used to amplify and record the signals from the strain gage Wheatstone bridges. Electrical wheel counters were utilized, so that wheel rpm and slip calculations could be made for the rear wheels.

The beams were calibrated in a tensile testing machine; the axle was calibrated by applying a torque to the axle through a specially constructed 11-foot lever. Force was applied to the lever with a hydraulic jack; the jack was set on a scale so that the force applied could be obtained.

Field testing was accomplished in the three following soils; a loam soil, a silty clay soil, and a clay soil.

Horsepower versus velocity plottings were made for the horsepower delivered to the rear wheels, the horsepower delivered to the rear wheels minus the horsepower lost to slippage, and the tillage unit horsepower for each of the three soils.

The relationship between required horsepower and velocity appeared to be linear, so statistical methods could be used to locate the curves. The horsepower standard errors were calculated for several velocities, so that expected ranges of horsepower could be set for the respective velocities in each soil.

Ranges of required horsepower were set for several speeds that included the expected horsepower requirements of the till-planter for most soils. This was possible since two extreme soils were represented in the tests. The ranges were defined by the maximum expected power required in the clay soil and the minimum power expected in the loam soil for a given speed.

The overall results of this investigation showed that the till-planter had advantages and disadvantages when compared with conventional tillage and planting methods. The major advantages noted were as follows:

1. The ground surface is protected by the crop residues up to the time of planting.

2. Most of the crop residues are left on the surface between the rows following planting.

3. The number of trips necessary to produce a crop is reduced since pre-tillage is unnecessary.

4. Heavier rates of fertilizer can be simultaneously applied with planting since a portion of the rate is distributed five inches below the planting depth.

The disadvantages noted were as follows:

1. Planting is delayed under wet conditions since a mulch covered soil dries out more slowly.

2. When the planting is delayed, the weeds get a good start; those left in the undisturbed strips are very hard to cut out with a cultivator.

3. Planting is slower with the till-planter; a tractor that can operate a four-row lister can only operate a two-row till-planter.